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A Methodology for Examining Collateral Effects on Military Operations during a Chemical, Biological, Radiological, and/or Nuclear Attack—Operational Effectiveness Loss Multiplier (OELM)

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14. ABSTRACT

This paper supplements the 2012 IDA Document D-4666 "Operational Effectiveness Analysis (OEA)," which focused on the development of a methodology for estimating losses to unit operational effectiveness resulting directly from exposure to a CBRN event. This paper concentrates on a methodology for estimating reductions to a military unit's operational effectiveness due to the collateral effects of a CBRN event, known as operational effectiveness loss multipliers (OELMs). For the OELM methodology, collateral effects are defined as consequences or impacts experienced in advance of, in concert with, subordinate to, or subsequent to the direct casualties that result from a CBRN event and reduce the operational effectiveness of individuals or units. OELMs are defined as "factors and requirements (including actions and activities in preparation or response to a CBRN event) that render either individuals or units ineffective or partially effective" because of the collateral effects on personnel occasioned by the CBRN event or requirements placed on personnel in preparation for or response to such an event. Among the OELMs are medical countermeasures (e.g., administration of post-exposure prophylaxis), nonmedical countermeasures (e.g., individual or collective protective equipment) response activities (e.g., decontamination and buddy aid), and indirect exposures (e.g., combat stress).

15. SUBJECT TERMS

Risk assessment; risk management; operation effectiveness; casualty estimation; risk level; combat stress; medical countermeasures; CBRN; biological agent; decontamination; post-exposure prophylaxis.

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Executive Summary

The military planning community has long sought methodologies to understand and estimate direct and collateral effects that occur in conjunction with and as a result of chemical, biological, radiological, and nuclear (CBRN) attacks on individual military personnel and units. Further, calculating and quantifying how those effects translate to decreases in operational effectiveness[1]—the ability of personnel or units to complete an assigned mission—after a CBRN event is a necessary step that informs operational readiness and medical, personnel, and logistical planning. Developing a methodology to evaluate operational effectiveness, however, poses many modeling and mathematical challenges, including the lack of human performance testing in CBRN scenarios;[2] the scarcity of parallels between CBRN agent symptoms in what little performance testing *has* occurred; and the presence of a host of complex factors that influence operational readiness.

In August 2012, the Institute for Defense Analyses (IDA) proposed the operational effectiveness analysis (OEA) methodology, a "methodology using the [Human Response Injury Profile] HRIP casualty estimation methodology, to represent the unit's operational ability to complete a mission following a CBRN event."[3] OEA allows for estimation of

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1 Operational effectiveness is the "measure of the overall ability of a system to accomplish a mission when used by representative personnel in the environment planned or expected for operational employment of the system considering organization, doctrine, tactics, supportability, survivability, vulnerability, and threat." Defense Acquisition University, *Glossary of Defense Acquisition Acronyms and Terms*, Fifteenth Edition, December 2012, accessed December 10, 2014, https://dap.dau.mil/glossary/pages/2334.aspx.

Operational readiness is defined as the "capability of a unit/formation, ship, weapon system, or equipment to perform the missions or functions for which it is organized or designed." Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, Joint Publication 1-02 (Washington, DC: November 2010), 184. http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf.

Due to the similarity of the two definitions and to avoid confusion of the methodology with the assessments of military operational readiness conducted in preparation for deployment, the research team selected operational effectiveness assessment as the title for the estimation methodology.

2 A scenario is defined as an account or synopsis of a projected course of action or events, with a focus on the strategic level of warfare. Scenarios include information such as threat, contexts and backgrounds, assumptions, constraints, limitations, strategic objectives, and other planning considerations. A scenario is intended to represent a plausible challenge(s) and may not reflect the most likely events.

3 Robert A. Zirkle et al., *Operational Effectiveness Analysis (OEA)*, Document D-4666 (Alexandria, VA: Institute for Defense Analyses (IDA), August 2012), iv.

operational effectiveness through a five-step process which incorporates casualty estimation data and tailored effectiveness level percentages for specified cohorts of personnel.

This paper supplements the 2012 IDA publication *Operational Effectiveness Analysis (OEA),*[4] which focused on the development of a methodology for estimating losses to unit operational effectiveness resulting directly from exposure to a CBRN event. It concentrates on a methodology for estimating individual military personnel and fractional reductions to a military unit's operational effectiveness due to the collateral effects[5] of a CBRN event,[6] known as operational effectiveness loss multipliers (OELMs).[7] For this effort, *OELMs* are defined as "factors and requirements (including actions and activities in preparation or response (AAPR) to a CBRN event) that render either individuals or units ineffective or partially effective"[8] because of the collateral effects on personnel occasioned by the CBRN event or requirements placed on personnel in preparation for or response to such an event.[9]

The population at risk (PAR)—the total number of troops included in the scenario characterization—can represent a small unit, such as a squad, or a larger unit, such as a company, battalion, regiment, or brigade. The operational effectiveness parameters provided in this paper are those expected to be appropriate to a brigade combat team (BCT) or a unit of similar size.

The OEA papers document the first analytic methodology to provide a framework for estimating increases in the numbers of individuals lost to a unit because of various

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4 Zirkle et al., *OEA.*

5 For the OELM methodology, collateral effects are defined as consequences or impacts experienced in advance of, in concert with, subordinate to, or subsequent to the direct casualties that result from a CBRN event and reduce the operational effectiveness of individuals or units.

6 The term *CBRN event* is used to indicate that the methodology may be applicable to any event that causes a CBRN-induced illness or injury, whether intentional, naturally occurring, or accidental.

7 In its original formulation, the OEA methodology referred to these as casualty multipliers. For capturing effects that may impact the whole population at risk (PAR) as well as impacts that result in potential, temporary reductions to operational effectiveness without resulting in casualties, these effects/impacts will hereafter be referred to as OELMs.

8 Zirkle et al., *OEA,* 14.

9 Preparation for CBRN events can include a number of measures including (1) deployment of monitoring and detection devices; (2) preparation of decontamination, triage, transfer, and contamination control sites; and (3) employment of mission-oriented protective posture (MOPP) equipment. The full range of preparation activities that could be modeled within the OELM methodology has not yet been evaluated.

As with preparation, response to CBRN events can include a number of activities and factors. The full range of response activities that could be modeled within the OELM methodology has not yet been evaluated.

collateral effects and activities associated with a CBRN event (e.g., adverse prophylaxis reactions, establishing a decontamination station, and combat stress (CS)). Although previous models have estimated unit performance following chemical or biological (CB) attacks, most of these models have not taken into account the additional anticipated losses to an individual or unit resulting from medical countermeasure (MCM) and non-medical countermeasure (NMCM) use,[10] response activities (RAs),[11] or indirect exposures (IXs).[12] The introduction of the OELM methodology allows military planners to quantify collateral effects in the OEA methodology, which may lead to improvement in the estimation of the operational effects on individuals, troops, and military units following a CBRN event. In addition, while developed for use with the OEA methodology, OELMs could be used with other models and methodologies.

OELMs could include anything that potentially causes a change in effectiveness but is not a direct result of casualty producing exposure to the CBRN agent(s).[13] This paper defines four categories of OELMs:

- MCMs, including losses due to medical material countermeasures (MMCMs);
- NMCMs, including losses due to public health interventions (PHI), individual protective equipment (IPE), and collective protection equipment (CPE);
- RAs; and
- IX, including CS.

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[10] Medical countermeasures are prevention and protection measures to eliminate or mitigate exposures to CBRN hazards and include medical materiel and public health interventions. They include those things that "directly affect the biology, metabolism, or status of the organism." See Michael Hopmeier, "Issues Associated with Population Protection from Disaster and Infectious Disease and the Role of Public Health" (briefing, Triangle Lecture Series, Center for Public Health Preparedness and Research, The Rollins School of Public Health of Emory University and The Department of Emergency Medicine, Emory University School of Medicine, Atlanta, GA, March 22, 2006).

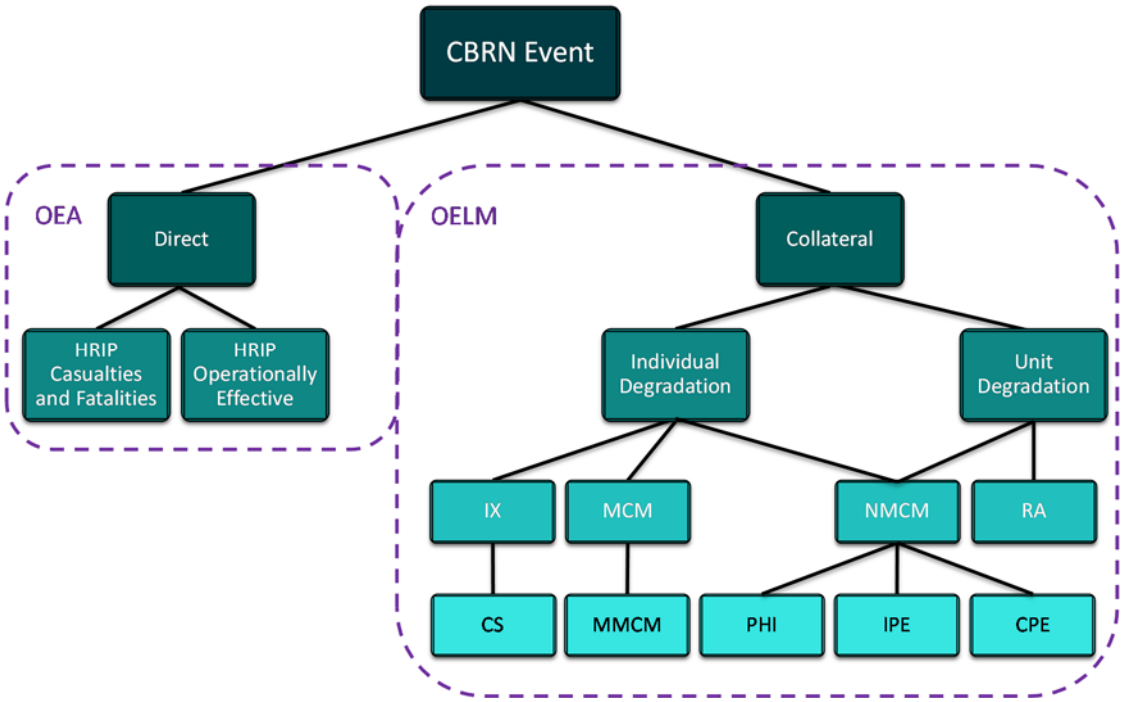
Non-medical countermeasures are "everything else: behavioral, materiel, social." Such countermeasures against CBRN include those materiel, actions, and procedures—non-medical in nature—necessary to mitigate or prevent further exposure to the CBRN agent. See Hopmeier, "Issues Associated with Population Protection from Disaster and Infectious Disease."

[11] Response activities are tasks or actions taken to "[address] the immediate and short-term effects of the disaster or emergency." See Department of Veterans Affairs (VA), *Veterans Health Administration Emergency Management Program Procedures*, VHA Handbook 0320.2 (Washington, DC: Veterans Health Administration, June 2000), A-3, http://www.va.gov/vhapublications/ViewPublication.asp?pub_ID=326. In VHA Handbook 0320.2, RAs are defined under the term "RESPONSE."

[12] Indirect exposures produce symptoms in individuals who were not exposed to the CBRN event, agent, or hazard in sufficient quantities to produce physiological symptoms but were aware of the event because of being present, witnessing the event at a distance, or experiencing the event through communication and contact with others.

[13] Zirkle et al., *OEA*, 14.

The calculation of operational effectiveness is conducted separately for direct impacts of the CBRN event due to the resulting physiological casualties (PCs) and the collateral effects of the event due to the AAPRs, illustrated as the HRIP-based and OELM hierarchies, respectively, in the following figure.



Hierarchies for the Calculation of Operational Effectiveness Assessments for Direct, Physiological Impacts and OELMs for Collateral Effects of CBRN Events

This paper will provide background information about HRIP and OEA to provide a foundation for the reader, further explain four OELM collateral effects categories, describe the OELM calculation, and demonstrate the methodology for three illustrative cases.

Contents

1. Introduction

The military planning community has long sought methodologies to understand and estimate direct and collateral effects that occur in conjunction with and as a result of chemical, biological, radiological, and nuclear (CBRN) attacks on individual military personnel and units. Further, calculating and quantifying how those effects translate to decreases in operational effectiveness[14]— the ability of personnel or units to complete an assigned mission—after a CBRN event is a necessary step that informs operational readiness and medical, personnel, and logistical planning. Developing a methodology to evaluate operational effectiveness, however, poses many modeling and mathematical challenges, including the lack of human performance testing in CBRN scenarios,[15] the scarcity of parallels between CBRN agent symptoms in what little performance testing *has* occurred, and the presence of a host of complex factors that change operational readiness.

While several models and methodologies are available to estimate the number of casualties and even the severity of injuries, thus far, few of these models and methodologies quantitatively produce the likely degradation of abilities that result from a CBRN attack.[16] In August 2012, the Institute for Defense Analyses (IDA) proposed the

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[14] *Operational effectiveness* is the "measure of the overall ability of a system to accomplish a mission when used by representative personnel in the environment planned or expected for operational employment of the system considering organization, doctrine, tactics, supportability, survivability, vulnerability, and threat." Defense Acquisition University, *Glossary of Defense Acquisition Acronyms and Terms*, Fifteenth Edition, December 2012, accessed December 10, 2014, https://dap.dau.mil/glossary/pages/2334.aspx.

Operational readiness is defined as "the capability of a unit/formation, ship, weapon system, or equipment to perform the missions or functions for which it is organized or designed." Department of Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, JP 1-02 (Washington, DC: November 2010), 184, http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf.

Due to the similarity of the two definitions and to avoid confusion of the methodology with the assessments of military operational readiness conducted in preparation for deployment, the research team selected operational effectiveness assessment as the title for the estimation methodology.

[15] A scenario is defined as an account or synopsis of a projected course of action or events, with a focus on the strategic level of warfare. Scenarios include information such as threat, contexts and backgrounds, assumptions, constraints, limitations, strategic objectives, and other planning considerations. A scenario is intended to represent a plausible challenge(s) and may not reflect the most likely events.

[16] Historically, the term performance has been used to define a measure for assessing an individual's capability in an operational setting, where performance is inversely proportional to the time it takes an individual to complete a specific set of tasks. Performance is estimated as part of the underlying calculation

(Continued)

operational effectiveness analysis (OEA) methodology, a "methodology using the HRIP [Human Response Injury Profile] casualty estimation methodology, to represent the unit's operational ability to complete a mission following a CBRN event."[17] OEA allows for the estimation of operational effectiveness through a five-step process that incorporates casualty estimation data and tailored effectiveness level percentages, as shown in Table 1, for specified cohorts of personnel.

Table 1. Operational Effectiveness Terms, Equivalent Personnel (P)-levels, and Occurrence Severity

Operational Effectiveness Term	Definition	P-level (% Available Strength)	Risk Severity (% Degradation)
Ineffective (IE)	Loss of ability to accomplish the mission or mission failure. Death or permanent disability.	P4 (< 70%)	Catastrophic (≥ 30%)
Partially effective (PE)	Significantly degraded mission capability, unit readiness, or personal disability.	P3 (≥ 70%) P2 (≥ 80%)	Critical (≥ 10%)
[Fully] effective (FE)	Little or no adverse impact on mission capability. First aid or minor medical treatment.	P1 (≥ 90%)	Marginal (≥ 1%) Negligible (< 1%)

Source: Robert A. Zirkle et al., *Operational Effectiveness Analysis (OEA),* Document D-4666 (Alexandria, VA: Institute for Defense Analyses (IDA), August 2012), 21.

This paper supplements the 2012 IDA publication *Operational Effectiveness Analysis (OEA),*[18] which focused on the development of a methodology for estimating losses to unit operational effectiveness that result directly from exposure to a CBRN event. It concentrates on a methodology for estimating reductions to unit operational

of casualties in the nuclear, chemical, and biological agent methodologies captured in the Nuclear, Biological, and Chemical Casualty and Resource Estimation Support Tool (NBC CREST), Version 4.0 and Version 5.0; however, it is not an output, and previous research by the Institute for Defense Analyses (IDA) suggests that the implementation of the human performance methodology into CBRN combat modeling suffers from a number of methodological problems. See Julia K. Burr et al., *Verification and Validation of the Representation of Human Response to Chemical Agents in NBC CREST Version 4.0,* Paper P-2478 (Alexandria, VA: Institute for Defense Analyses (IDA), 2008).

17 Robert A. Zirkle et al., *Operational Effectiveness Analysis (OEA),* Document D-4666 (Alexandria, VA: Institute for Defense Analyses (IDA), August 2012), iv.

18 Ibid.

effectiveness due to collateral effects[19] of a CBRN event,[20] known as operational effectiveness loss multipliers (OELMs). In its original formulation, the OEA methodology employed the term casualty multipliers, which were defined as follows:

> … factors and requirements that render some individuals or some fraction of the unit ineffective or partially effective because of the direct impacts on personnel or requirements placed on the personnel by the CBRN event. There are several potential examples of casualty multipliers including: combat stress casualties (CSC), casualties (or symptoms) due to medical countermeasures (CMC) implementation, casualties (or symptoms) due to non-medical implementation, and buddy aid.[21]

The term *casualty multiplier* was originally chosen to indicate the mathematical value by which direct casualties (those casualties that result directly from exposure to a CBRN event) could be multiplied to estimate the number of indirect casualties (those casualties that result indirectly from the exposure or potential exposure to CBRN agents). Indirect casualties could result from a number of different scenarios, including heat stress while wearing protective equipment,[22] adverse reactions to medical countermeasures, or psychological stress experienced by those exposed to CBRN agents at levels not high enough to cause casualties.

Subsequently, the more inclusive term *OELM* was chosen to replace casualty multiplier as the IDA research came to understand that operational effectiveness could degrade due to additional phenomena. Specifically, losses to a military unit's operational effectiveness could also result from activities and actions in preparation or response (AAPR) to the event including, but not limited to, donning personal protective equipment, decontamination, and buddy aid. Review of several of these AAPRs demonstrated that estimates of indirect casualties can be based on either the number of direct casualties or the total population at risk (PAR) (i.e., the total number of troops included in the scenario characterization). In addition, those same AAPRs could cause temporary losses to a unit's operational effectiveness not as a result of personnel casualties but due either to the activities and actions taken to prevent casualties or the effects of those activities and actions. OELM encompasses both casualty multipliers and

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19 For the OELM methodology, collateral effects are defined as consequences or impacts experienced in advance of, in concert with, subordinate to, or subsequent to the direct casualties that result from a CBRN event and reduce the operational effectiveness of individuals or units.

20 The term *CBRN event* is used to indicate that the methodology may be applicable to any event that causes a CBRN-induced illness or injury, whether intentional, naturally occurring, or accidental.

21 Zirkle et al., *OEA*, 14.

22 There are possible ways to avoid these effects. For example, if work/rest cycles are managed correctly, the operational loss is due to shortened work cycles rather than heat stress.

those multiplication factors used to estimate other unit losses due to AAPRs as consequences of a CBRN event.

OELMs could include anything that potentially causes a change in effectiveness but is not a direct result of casualty-producing exposure to the CBRN agent.[23] This paper defines four categories[24] of OELMs and several subordinate subcategories:[25]

- medical countermeasures (MCMs), including losses due to medical material countermeasures (MMCMs);
- non-medical countermeasures (NMCMs), including losses due to public health interventions (PHIs), individual protective equipment (IPE), and collective protection equipment (CPE);
- response activities (RAs); and
- indirect exposures (IXs), including combat stress (CS).

Note that the first three OELM categories correspond to AAPRs. Within each category or subcategory, as applicable, there may be classes to describe specific OELMs applicable before or after a CBRN event or contingent on the type of CBRN event (i.e. post-exposure prophylaxis (PEP) or chemical agent personnel decontamination). The calculation of operational effectiveness is conducted separately for direct impacts of the CBRN event due to the resulting physiological casualties and the collateral impacts of the event due to OELMs, illustrated as the HRIP-based and OELM hierarchies, respectively, in Figure 1.

This paper explains the OELM categories and describes how the OELM methodology estimates the resulting loss in unit effectiveness due to the indirect effects of a CBRN event. In addition, it begins to demonstrate the methodology for developing OELM parameters, using three illustrative cases.

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[23] Zirkle et al., *OEA*, 14.

[24] For the OELM methodology, a category is the term used to describe the general types of AAPRs applicable before or after a CBRN event that may affect individual and/or unit operational effectiveness.

[25] For the OELM methodology, a subcategory is a further division of the OELM categories. Each subcategory can represent one or more specific AAPRs applicable to one or more C, B, R, or N events, otherwise known as classes.

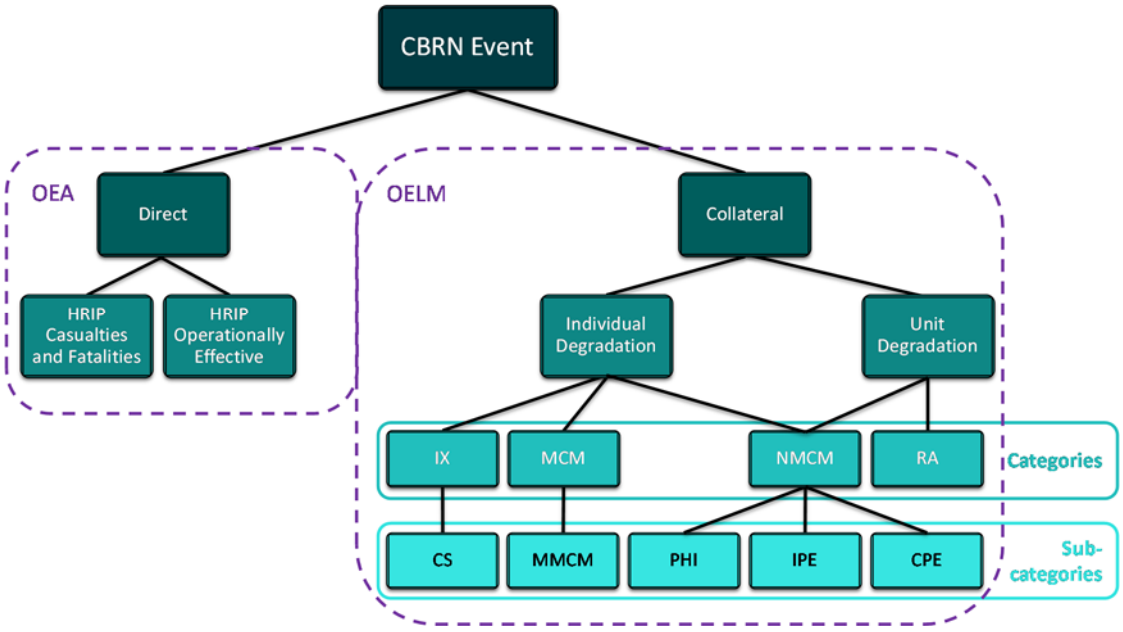

Figure 1. Hierarchies for the Calculation of Operational Effectiveness Assessments for Direct, Physiological Impacts and OELM for Collateral Effects of CBRN Events

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2. Background

Historically, the assessment of an individual's ability to perform in an operational setting was either based on the time required to carry out a series of tasks with and without symptoms.[26] Research conducted by IDA during a previous project regarding the performance methodology as implemented in the NBC CREST model suggested methodological problems and inconsistencies in this approach.[27] Nevertheless, some measure of operational effectiveness is still desired by commanders and is not yet available in the current hazard assessment tool set, including the Joint Effects Model (JEM) and the Joint Warning Network (JWARN) (currently in development by the Chemical/Biological Defense Program (CBDP)).

In 2010, at the request of the Office of the Army Surgeon General in its role as the chair of the North Atlantic Treaty Organization (NATO) CBRN Medical Working Group, IDA developed the HRIP methodology for estimating casualties resulting from CBRN hazards. HRIP uses symptom and injury severity, based on total agent dose, as a function of time and user-defined casualty criteria to determine changes in personnel status—operational or casualty, including wounded in action (WIA) and fatal casualties (also known as fatalities (Ftl))—over time. In 2011, the Defense Threat Reduction Agency (DTRA) asked IDA to consider how capability, or operational effectiveness, could be assessed using HRIP.

With this guidance, IDA developed the OEA methodology, which uses the output from HRIP (changes in personnel status over time) to represent the unit's operational ability to complete a mission following a CBRN event. The proposed OEA methodology provides the commander a quantitative, qualitative, and graphical representation of the unit's operational effectiveness as a function of effective personnel, fatalities, symptomatic non-casualties (SNC), and OELMs. The model provides a simplified process to estimate a unit's operational effectiveness following a CBRN event, with the potential to easily integrate more detailed analysis as data become available.

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[26] G. H. Anno et al., *Predicted Performance on Infantry and Artillery Personnel Following Acute Radiation or Chemical Agent Exposure*, DNA-TR-93-174 (Washington, DC: Defense Nuclear Agency, 1994).

[27] Burr et al., *Verification and Validation of NBC CREST*.

The OEA methodology as presented in *Operational Effectiveness Analysis*,[28] defines four cohorts following a CBRN attack. Specifically, personnel will be placed in a cohort based on their personnel status: unaffected (Un), casualties (including WIAs and fatalities), SNCs, and collateral losses due to OELMs, including those who are partially effective and those who are ineffective due to their collateral effects. The proof-of-concept example was outlined in the Zirkle et al. publication but did not fully consider the impact of casualty multipliers, because a separate methodology for assessing these multipliers had not yet been developed. Casualty multipliers, and more generally OELMs, are factors and requirements that render some individuals or some fraction of the unit ineffective or partially effective because of the collateral impacts on the personnel or requirements placed on the personnel by the CBRN event or in preparation for or response to such an event.[29] Examples of AAPRs that would lead to OELM-related losses include donning IPE that may impair movement and the senses; buddy aid; decontamination; reactions to vaccinations; and CS. Based on the quantity of possible OELMs and the likelihood that different types of OELMs would require different approaches, IDA determined that a separate methodology would be required to quantify and incorporate OELMs into the OEA methodology.

A. Human Response Injury Profile (HRIP)

The HRIP casualty estimation methodology uses three different approaches to provide an estimate of casualties that occur as a consequence of CBRN attacks against military targets, depending on the agent type: chemical, radiological, and nuclear (CRN); contagious biological; and non-contagious biological. A series of maps, or progressions, of underlying symptoms (and signs for biological agents) and their severity over time are used to estimate personnel status. The CRN and non-contagious biological HRIP methodologies provide deterministic representations of stochastic injury and illness progressions, respectively, while the contagious biological HRIP methodology uses a simple stochastic process to estimate human response and illness progression over time. HRIP converts human physiological responses to CBRN agents into a personnel status as a function of time, based on the severity of symptoms, and outputs casualty and fatality

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[28] Zirkle et al., *OEA.*

[29] Preparation for CBRN events can include a number of measures including (1) deployment of monitoring and detection devices; (2) preparation of decontamination, triage, transfer, and contamination control sites; and (3) employment of mission-oriented protective posture (MOPP) equipment. The full range of preparation activities that could be modeled within the OELM methodology has not yet been evaluated.

As with preparation, response to CBRN events can include a number of activities and factors. The full range of response activities that could be modeled within the OELM methodology has not yet been evaluated. See Zirkle et al., *OEA*, 14.

estimates.[30] These outputs are typically given in tables of personnel status over time but can also be presented graphically.

Commanders (or other users of the methodology) select the injury severity level (SL)—either SL 1 (mild), SL 2 (moderate), or SL 3 (severe)—at which their soldiers seek medical attention. When military personnel are estimated to first exhibit symptoms that meet or exceed the chosen SL, these personnel become WIA, and they are lost to their unit.[31] Personnel who reach SL 4 (very severe) are expected to die without extensive medical treatment that may or may not be available in theater. The number of individuals in a given state at a given time will be used as an input to the OEA methodology.

B. Operational Effectiveness Analysis (OEA)

The OEA methodology uses the HRIP personnel status output[32] and user-defined constants to determine the overall effectiveness of a unit following a CBRN attack. The following steps are a basic guide to this methodology, which was described in further detail in IDA's previous operational effectiveness paper.[33]

- **Step 1: Select OEA parameters for use in HRIP and OEA methodologies.** The commander or user begins the OEA process by identifying the HRIP casualty threshold—the injury SL at which individuals are expected to seek (or be directed into) medical treatment—and the operational effectiveness factors for each cohort.
- **Step 2: Estimate the basic operational effectiveness values for each cohort over time using the HRIP methodology.** For a given scenario, the HRIP methodology provides data that allow the OEA user to determine the number of individuals and/or the fraction of the unit over time who are Un, WIAs, fatalities, and SNCs for a given casualty threshold. Using the number of individuals, or fraction of the unit, in each cohort and the operational effectiveness values selected in Step 1, the basic operational effectiveness of the unit over time can

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30 For a quick summary of the HRIP methodology, see Deena S. Disraelly et al., "A New Methodology for Chemical, Biological, Radiological, and Nuclear [CBRN] Casualty Estimation over Time," *Journal of Defense Modeling and Simulation* 7, no. 4 (2010): 226–240, http://dms.sagepub.com/content/7/4/226.refs.

31 Injury SL 0—no observable effects—is reserved for those personnel currently unaffected by the agent.

32 The HRIP methodology outputs unaffected, casualties (determined at a symptom severity threshold defined by the Commander), and fatalities over time, as well as the SL of symptoms for symptomatic non-casualties. Other casualty methodologies could be also used as inputs to the OEA methodology if outputs are similar.

33 Zirkle et al., *OEA*, 13–22.

be calculated by multiplying the cohort percentage by the operational effectiveness value.

- **Step 3: Estimate the impact of OELMs on the unit's operational effectiveness.** The methodology for determining the impact of OELMs is discussed in Chapter 4 of this paper.
- **Step 4: Determine the cumulative quantitative operational effectiveness of the unit over time.** The cumulative quantitative operational effectiveness combines the operational effectiveness of the unit due to the direct effects of the CBRN event and the collateral effects of the implemented AAPRs. The total number of casualties may need to be recalculated depending on what preparatory AAPRs are used (i.e., MCMs, NMCMs).
- **Step 5: Graphically determine the quantitative operational effectiveness of the unit over time.** Using the values calculated in Step 4, graph the total operational effectiveness over time.

3. Relevant Definitions

For completeness and clarity, the definitions of the terms used in the OEA methodology and for proposed OELMs, as well as terms used in the methodology and illustrative examples, are defined.

A. OEA Cohorts

The OEA methodology consists of a number of different cohorts that describe personnel status at a given point in time. Individuals may move from one cohort to another at different points in time depending on their exposure (e.g., a disease progresses) and the collateral effects of their AAPRs (e.g., protection is sought). At the start of any scenario, there is a PAR made up of unaffected individuals (the Un cohort). The HRIP methodology describes how, due to the direct effects of a CBRN event, individuals can move through the cohorts after such an event. Some remain in the Un cohort, and others become SNCs and casualties, as shown in Figure 2.

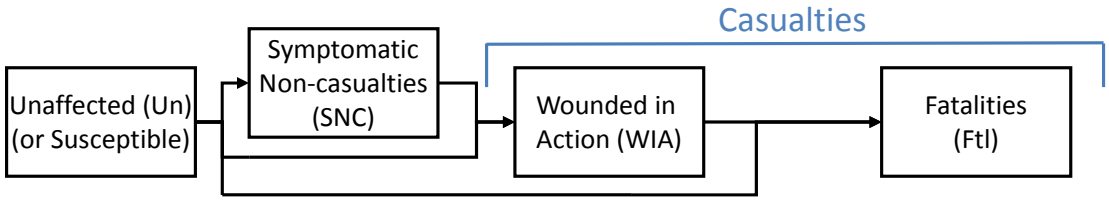

Figure 2. Cohorts Described in the HRIP Methodology

In the OELM methodology, some casualties also may be the result of AAPRs. For example, casualties could arise due to adverse effects following prophylaxis. Some individuals or fractions of units, however, experience degradation that does not lead to becoming a casualty. For example, individuals wearing IPE may experience degradation in their ability to perform the mission because they are wearing gloves and masks, while a unit's ability to perform a mission may be degraded when unit members are re-tasked to perform buddy aid. Therefore, the OELM methodology may require one or more additional "loss" cohorts to capture the numbers of individuals or the fraction of the unit whose operational effectiveness is degraded either temporarily or for longer term due to AAPRs. Figure 3 shows the cohorts for both the direct and collateral effects.

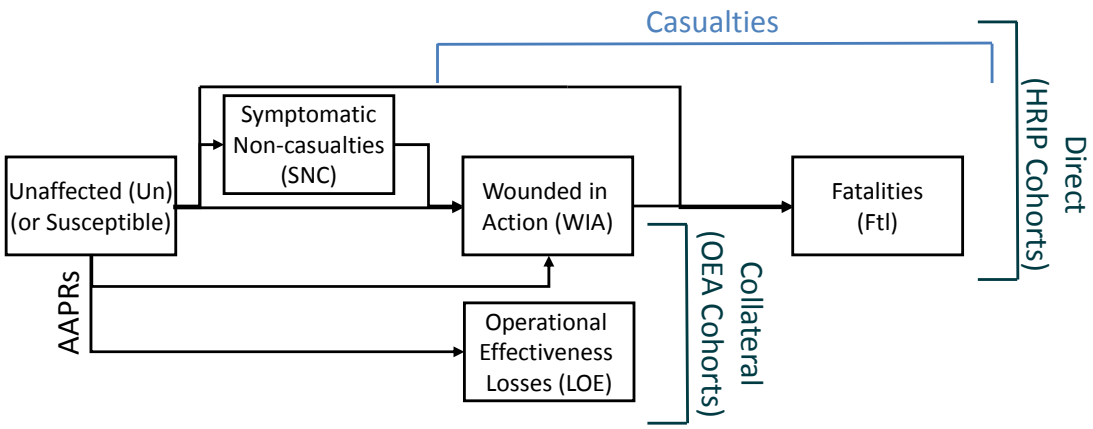

Figure 3. Direct and Collateral Effects Cohorts

Each cohort has one or more suggested, associated effectiveness percentages. These values can be changed from their default values by the commander or analyst using the OEA methodology. The cohort definitions are provided in the following subsections.

1. Unaffected (Un)

The Un cohort consists of the individuals in the unit, or fraction of the unit, who are directly unaffected by the CBRN event. They "may be unaffected for several reasons including, but not limited to (1) unexposed; (2) exposed at levels that will not result in symptoms or have not yet caused symptoms; or (3) protected by non-medical countermeasures including IPE and collective protection and/or MCM,"[34] with no adverse effects arising from the use of these countermeasures. Personnel in this cohort remain 100% operationally effective but are reevaluated at each time period and may move to a different cohort, for example, if they start to exhibit symptoms due to direct exposure or develop operational effectiveness degradation from the use of their NMCMs or MMCMs.

2. Casualties (Cas)

Based on the NATO definition, a casualty is "any person who is lost to his organization by reason of having been declared dead, wounded, diseased, detained, captured, or missing."[35] The HRIP methodology expanded the definition to specify that casualties

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[34] Zirkle et al., *OEA*, 13.

[35] North Atlantic Treaty Organization (NATO) Standardization Agency (NSA), *NATO Glossary of Terms and Definitions (English and French)*, Allied Administration Publication (AAP)-06, Edition 2012 Version 2 (hereafter referred to as AAP-06 (2012)) (Belgium: NSA, 2012), 2-C-2.

occurred "as a result of exposure to a chemical agent, biological agent, radiological agent, or nuclear flash, blast, heat or radiation."[36] Casualties include both WIAs and fatalities.

Wounded in action (WIA)

A WIA is defined by NATO as a casualty "other than 'killed in action' who has incurred an injury due to an external agent or cause."[37] In the HRIP methodology, WIA is typically applied to battle casualties, those casualties that are "the direct result of hostile action, sustained in combat or relating thereto or sustained going to or returning from a combat mission."[38] To avoid the introduction of additional terminology and for the OEA and OELM methodologies, the term WIA is expanded to include any injury (not leading to "killed in action") incurred in the line of duty. In other words, WIA will apply to any "injury, illness, or disease … incurred or aggravated as a result of military duty not due to gross negligence or misconduct."[39] Therefore, WIA includes those who experience injury due to direct exposure to a CBRN event—regardless of whether the source was hostile, unintentional, or accidental—and those who experience injury as a result of the collateral effects of the CBRN event.[40] Therefore, the OELM methodology considers two types of WIAs: those resulting from direct effects (WIA_D) and those resulting from collateral effects (WIA_C).

In the HRIP methodology, a WIA threshold is associated with the injury SL at which individuals would be expected to seek medical attention as a result of direct effects of the CBRN hazard.[41] The potential SLs are *mild injury* (SL 1), *moderate injury* (SL 2), *severe injury* (SL 3), and *very severe injury* (SL 4).

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36 Disraelly et al., "A New Methodology for CBRN Casualty Estimation over Time," 228.

37 North Atlantic Treaty Organization (NATO) Standardization Agency (NSA), *NATO Glossary of Terms and Definitions (English and French)*, Allied Administration Publication (AAP)-6 Edition 2008 (Belgium: NSA, 2008), 2-W-2 (hereafter referred to as AAP-6 (2008)), https://www.fas.org/irp/doddir/other/nato2008.pdf.

AAP-06 proposes a slightly different definition: a casualty "who has incurred a non-fatal injury due to an external agent or cause as a result of hostile action." (AAP-06 (2012), 2-W-2.) To avoid any confusion or implication that WIAs cannot eventually die as a result of their injuries, the earlier definition from AAP-6 (2008) is used for the OEA methodology.

38 North Atlantic Treaty Organization (NATO) Standardization Agency (NSA), AAP-06, 2012, 2-B-2.

39 Department of Defense, *Reserve Component Medical Care and Incapacitation Pay for Line of Duty Conditions*, DoD Directive (DoDD) 1241.01 (Washington, DC: USD(P&R), April 23, 2007), 2, http://www.dtic.mil/whs/directives/corres/pdf/124101p.pdf.

40 Some individuals who experience collateral effects and participate in AAPRs will have reduced operational effectiveness but will not be casualties.

41 For more information on the HRIP Methodology and the casualty threshold, see Disraelly et al., "A New Methodology for CBRN Casualty Estimation over Time," 226–240.

For the OEA methodology and its intended use with U.S. forces, IDA recommends a default WIA threshold value of moderate injury (i.e., those symptoms usually requiring individuals to seek medical attention—for example, difficulty in concentration, episodes of vomiting, fever, or non-productive cough).[42] These individuals will be lost to their unit for the period during which they are in the medical system. They will, for the OEA methodology, be considered operationally ineffective until they are determined to be well and/or returned to duty.

Fatalities (Ftl)

The HRIP methodology distinguishes between two types fatalities: individuals who die outright or before seeking medical attention, known as killed in action (KIA),[43] and individuals who die after seeking medical attention, known as died of wounds (DOW).[44] Individuals who become fatalities are considered to be operationally ineffective because they are lost to their unit permanently.

3. Symptomatic Non-Casualties (SNCs)

Consistent with the earlier OEA publication, SNCs "are those individuals in the unit, or the fraction of the unit, who exhibit symptoms but whose symptoms are not yet of a severity requiring them to (or resulting in the expectation that they would) seek medical attention. Despite this, the symptoms may still result in some degradation of operational effectiveness depending on their severity, rendering them partially effective."[45] For some SNCs, the symptoms may never reach a severity that requires them to seek medical attention.

As with WIAs, the SNC cohort may include those individuals who experience symptoms due to direct exposure (SNC_D) and those individuals who experience symptoms because of the collateral effects of the CBRN event (SNC_C).

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42 North Atlantic Treaty Organization (NATO), *North Atlantic Treaty Organization (NATO) Medical Planning Guide for the Estimation of Chemical, Biological, Radiological, and Nuclear (CBRN) Casualties Ratification Draft,* Allied Medical Publication 8(C) (Brussels: NATO, 2011).

NATO recommends a WIA threshold associated with mild injury, typically considered nuisance symptoms including rhinorrhea (runny nose) and nausea.

43 AAP-06 (2012), 2-K-1.

44 Ibid., 2-D-6.

45 Zirkle et al., *OEA,* 14.

4. Operational Effectiveness Losses (LOEs)

In addition to the casualties incurred as a result of the AAPRs, some individuals or units may be tasked to perform AAPRs that take them away from their primary mission for a period of time. These individuals are fully (or partially) effective; however, for some period of time, they are ineffective at their unit mission while performing other AAPRs.

These LOEs are distinct from the HRIP-defined casualties, as noted previously. While they are a complete loss to the unit, these losses are temporary and due to the collateral effects of AAPRs (the ancillary procedures and requirements that stem from the unique nature of a CBRN event), rather than loss due to the physiological symptoms resulting directly or collaterally from the CBRN *insult.*[46]

B. OELM Categories

The operational impact of a CBRN event cannot be encapsulated strictly in terms of WIAs, fatalities, and SNCs as defined by the HRIP methodology. The OELM methodology also introduces LOEs. Therefore, this paper describes additional, collateral factors that influence operational effectiveness, captured by the OELMs, in four categories:

- MCMs (medical countermeasures),
- NMCMs (non-medical countermeasures),
- RAs (response activities), and
- IXs (indirect exposures).

Each of these categories, in turn, may include a number of different subcategories to further divide and differentiate the OELMs in each category. For the first three OELM categories (i.e., the AAPR-related categories), each subcategory is further divided into classes describing specific AAPRs applicable before or after a CBRN event and [potentially] contingent on the type of CBRN event.[47] For example, the RA category includes at least two subcategories (decontamination and buddy aid), while the MCM category currently includes one subcategory (MMCMs) divided into numerous classes to include different types of vaccines, prophylaxis, and treatment. Subclasses further differentiate AAPRs within each class that may be applicable to different portions of the PAR or for varying times. For example, some small portion of the military population that is allergic to doxycycline might be administered ciprofloxacin PEP; doxycycline and ciprofloxacin

[46] Insults are defined as chemical and biological agents, radiation, blast, or thermal energy that result from CBRN events that produce direct physiological symptoms and casualties.

[47] At present, the research team does not anticipate that indirect exposures will be divided below the subcategory level.

would represent two subclasses of the PEP class. Similarly, during chemical decontamination, different job assignments will last longer than others, thereby varying the duration of operational effectiveness loss for the different unit members performing each task; each job assignment would constitute a different subclass within the chemical decontamination class.

The collateral effects may be cumulative at the class level or may be further divided into subclasses. To help clarify these terms, Figure 4 illustrates two examples of how the terminology applies.

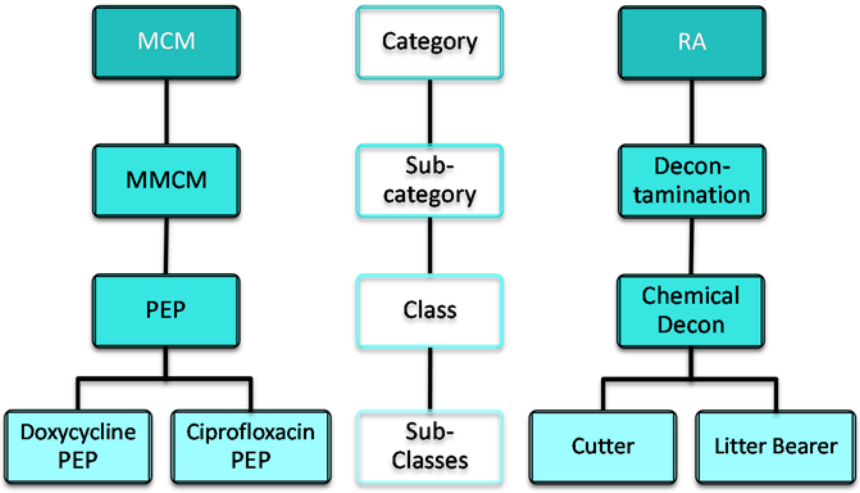

Figure 4. Two Examples of OELM Categories, Subcategories, Classes, and Subclasses

Not every multiplier or collateral effect will be appropriate for every scenario, and additional OELM categories and subcategories not included in this paper may be considered at a later date.

1. Medical Countermeasures (MCMs)

MCMs against CBRN are prevention and protection measures and procedures to eliminate or mitigate exposures to chemical, biological, and radiological hazards, as well as nuclear-weapon-related radiation, blast, and thermal insults. According to the Department of Defense (DOD), MCMs "range from the routine management of medical materiel used for individual protection to planning responses for events that may produce catastrophic numbers of casualties."[48] They include those things that "directly affect the

[48] Department of Defense, *Health Service Support,* JP 4-02 (Washington, DC: Joint Staff, 26 July 2012), D-21, http://www.dtic.mil/doctrine/new_pubs/jp4_02.pdf.

biology, metabolism, or status of the organism"[49] or the individual experiencing the CBRN physiological symptoms.

For this paper, the IDA research team has included one subcategory in medical countermeasures: MMCMs (medical materiel countermeasures).

Medical materiel countermeasures (MMCMs)

For this paper, MMCMs are pharmaceutical countermeasures and will include three classes: vaccines, prophylaxis (both pre- and post-exposure), and post-exposure treatment (such as antibiotics). Not all CBRN agents will have an effective MMCM nor will every countermeasure have equal effectiveness.

This OELM subcategory causes loss of operational effectiveness when individuals are incapacitated or suffer degradation in their capabilities due to drug side effects or adverse reactions. The losses due to MMCMs will be calculated based on the expected availability of a particular MMCM, the anticipated severity of the adverse effects from taking or receiving this MMCM (i.e., the anticipating operational effectiveness decrement), and the fraction of the PAR expected to suffer these adverse effects.

2. Non-medical Countermeasures (NMCMs)

Given that MCMs are the things that directly affect the biology or metabolism of the individual experiencing symptoms resulting from the CBRN event, NMCMs are "every-thing else: behavioral, materiel, social."[50] NMCMs against CBRN include those materiel, actions, and procedures—non-medical in nature—necessary to mitigate or prevent further exposure to the CBRN agent.

For this paper, the IDA research team has divided NMCMs into three subcategories: PHIs (public health interventions), IPE (individual protective equipment) and CPE (col-lective protection equipment).

Public health interventions (PHIs)

PHIs include those actions necessary to mitigate or prevent further exposure to the CBRN agent. Social distancing and quarantining of personnel are two examples of this subcategory. The losses due to public health intervention will result from the operational

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[49] Michael Hopmeier, "Issues Associated with Population Protection from Disaster and Infectious Disease and the Role of Public Health" (briefing, Triangle Lecture Series, Center for Public Health Preparedness and Research, The Rollins School of Public Health of Emory University and The Department of Emergency Medicine, Emory University School of Medicine, Atlanta, GA, March 22, 2006).

[50] Ibid.

effectiveness degradation associated with employing these actions (e.g., removing individuals from the general population due to quarantine will restrict their ability to contribute to the mission). These losses will be calculated as a function of the anticipated degradation in operational effectiveness arising from the actions taken and the fraction of the PAR to whom the actions are expected to apply.

Individual protective equipment (IPE)

The DOD defines IPEs in the following manner: "In chemical, biological, radiological, or nuclear operations, [IPE is] the personal clothing and equipment required to protect an individual from chemical, biological, and radiological hazards and some nuclear hazards."[51] Mission-oriented protective posture (MOPP) gear, overboots, and masks fall into this subcategory. The losses due to individual protective equipment will result from the operational effectiveness degradation associated with employing these materials (e.g., wearing IPE such as masks and gloves can impede communication and small motor skill tasks). These losses will be calculated as a function of the anticipated degradation in operational effectiveness arising from the employment of the particular IPE and the fraction of the PAR expected to experience this degradation.[52]

Collective protection equipment (CPE)

CPE is used to provide protection "to a group of individuals that permits relaxation of individual chemical, biological, radiological, and nuclear protection."[53] The losses due to collective protection equipment will result from the operational effectiveness degradation associated with employing these materials (e.g., enclosing individuals inside a vehicle that employs CPE can increase the heat load on individuals and result in performance degradation). These losses will be calculated as a function of the anticipated degradation in operational effectiveness that arises from the employment of the particular CPE (or the restriction of unit activities due to the CPE) and the fraction of the PAR expected to experience this degradation.

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51 Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, 117–118.

52 Wearing IPE may also, potentially, result in losses due to heat exhaustion and heat casualties. These losses will not explicitly be addressed in this paper but may be revisited in future OELM case studies.

53 Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, 36. In JP 1-02, CPE is defined under the term "collective protection."

3. Response Activities (RAs)

RAs are tasks or actions taken to "[address] the immediate and short-term effects of the disaster or emergency."[54] RAs cause operational effectiveness losses because the individuals performing the activities are a loss to the principal mission for as long as required to complete the task. Losses due to response activities are those individuals who are temporarily removed from mission-related tasks to attend to the particular event response.

Two subcategories of RAs are defined for this paper: decontamination and buddy aid. Other RAs may be considered at a later date.

Decontamination

Decontamination includes using unaffected, mission-capable forces to perform the processes necessary to mitigate exposure and take the required actions to allow contaminated individuals and equipment to be returned to duty and contaminated patients to be stabilized for medical treatment. Individuals performing decontamination are operationally ineffective for the duration of the time that they are involved in the decontamination process.

Buddy aid

The DOD defines buddy aid as "acute medical care (first aid) provided by a nonmedical Service member to another person."[55] According to JP 4-02, "all military personnel are trained in a variety of basic-first-aid procedures. These procedures include aid for chemical casualties with particular emphasis on lifesaving tasks. This training enables the military personnel to apply first aid to alleviate potential life-threatening situations."[56] Buddy aid is considered part of the Role 1 unit-level medical care, which includes the following:

> (a) Immediate lifesaving measures.
>
> (b) DNBI [disease non-battle injury] prevention and care.
>
> (c) Combat and operational stress preventive measures.
>
> (d) Patient location and acquisition (collection).
>
> (e) Treatment provided by designated combat medics … (Major emphasis is placed on those measures necessary for the patient to return to duty or to

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54 Department of Veterans Affairs. *Veterans Health Administration Emergency Management Program Procedures.* VHA Handbook 0320.2 (Washington DC: Veterans Health Administration, June 2000), A-3, http://www.va.gov/vhapublications/ViewPublication.asp?pub_ID=326. In VHA Handbook 0320.2, RAs are defined under the term "RESPONSE."

55 Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, 26.

56 Department of Defense, *Health Service Support*, III-1.

> stabilize him and allow his evacuation to the next role of care. These measures include maintaining the airway, stopping bleeding, preventing shock, protecting wounds, immobilizing fractures, and other emergency measures, as indicated).[57]

Individuals performing buddy aid are operationally ineffective for the duration of the time that they are involved in the buddy-aid process.

4. Indirect Exposures (IXs)

An IX produces symptoms in individuals who were not directly exposed to the CBRN event, agent, or hazard in sufficient quantities to produce physiological symptoms but were aware of the event because of being present, witnessing the event at a distance, or experiencing the event through secondary or tertiary effects[58] or communication and contact with others. IXs cause operational effectiveness losses because the individuals who experienced the CBRN event are now manifesting symptoms that may cause them to become SNCs or casualties and therefore may become partially effective or operationally ineffective depending on the nature and severity of the symptoms.

One example of an IX—CS (combat stress)—is defined for this paper. Other IXs may be considered at a later date.[59]

Combat Stress (CS)

The Marine Corps defines CS as the "the mental, emotional or physical tension, strain, or distress resulting from exposure to combat and combat-related conditions."[60] Expanding on this definition, Marine Corps publications state:

> Combat stress reactions are the result of exposure to the same conditions during military actions that cause physical injury and disease in battle or its immediate aftermath … Rates of combat stress casualties vary greatly, with higher ratios during lengthy periods of intense combat.[61]

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57 Ibid.

58 The HRIP methodology accounts for decelerative tumbling, which is a tertiary effect; however, it is currently the only such secondary or higher order nuclear effect contained in the methodology. The OELM methodology may eventually examine higher order effects, including glass breakage, that would be a form of a secondary effect called *missiling*.

59 Such exposures could include, for example, flash blindness or glass breakage (resultant from secondary blast effects) injury following a nuclear detonation. Because approaches to these examples have not been explored by the research team, they are not yet defined for this methodology.

60 U.S. Marine Corps, *Combat Stress*, FM 90-446/6-22.5/NTTP 1-15M/MMCRP 6-11C (Washington, DC: Headquarters, USMC, 2000), Preface, http://www.au.af.mil/au/awc/awcgate/usmc/mcrp611c.pdf.

61 Ibid.

CS reactions "may also arise from combat-like conditions present during military operations other than war."[62] CS reactions cause "changes in physical or mental functioning or behavior …" [which] "… can be positive and adaptive or … negative, including distress or loss of normal functioning."[63] Further, individuals experiencing CS are not suffering from a psychiatric disorder; rather, CS is considered a normal emotional and/or physical reaction.[64]

Losses due to combat stress, therefore, entail those individuals experiencing loss of operational effectiveness due to CS. Because positive and adaptive changes would not be expected to reduce operational effectiveness, individuals experiencing these effects are excluded from these losses. By contrast, negative emotional and physical distress could cause operational effectiveness losses.

C. Additional OELM Terms

Two additional terms are required to facilitate the OELM evaluation: population at risk (PAR) and post-event population at risk (PE-PAR).

1. Population at Risk (PAR)

The PAR is the total number of troops included in the scenario characterization.[65]

2. Post-Event Population at Risk (PE-PAR)

The PE-PAR is the total number of troops to which OELMs can be applied. Depending on the nature of the OELM, this group can include only those unaffected by the CBRN incident or it could be defined by

$$\text{PE-PAR}_{Category,Subcategory,Class}(t) = \text{PAR} - (\text{WIA}_D(t) + \text{WIA}_C(t) + \text{LOE}(t) + \text{Ftl}(t)) \quad \text{for } t = \text{time of OELM class initiation.}$$

The fatalities (Ftl) cohort includes DOWs and KIAs.

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62 Ibid.

63 U.S. Marine Corps, *Combat and Operational Stress Control*, MCRP 6-11C/NTTP 1-15M (Washington, DC: Department of the Navy, Headquarters United States Marine Corps, 20 December 2010), 1-3, http://www.namb.net/uploadedFiles/COSC%201.pdf.

64 Department of Defense, "Combat Stress" (briefing, Bethesda, MD: DoD Deployment Health Clinical Center (DHCC), 2006), http://www.pdhealth.mil/downloads/AFCombatStressforMedicalProvidersAug06.pdf.

65 D. S. Disraelly et al., "A New Methodology for Estimating Nerve Agent (Sarin (GB)/VX) Casualties as a Function of Time: Implementing the Human Response Injury Profile Nerve Agent Methodology," *Journal of Chemical Health and Safety* 18, no. 5 (2011): 15, http://www.sciencedirect.com/science/article/pii/S1871553210000939#.

3. Residual Operational Effectiveness (ROE)

The ROE is the fraction of operational effectiveness that remains after the direct effects of the CBRN event occur and after the initiation of any OELM. For the unaffected (Un) cohort—those who are fully *operationally effective*—the ROE is 1. For those who are *operationally ineffective*—WIA_D, WIA_C, LOE, and fatalities (Ftl) cohorts—the ROE is 0. For those who are partially effective, the ROE is some value between 0 and 1.

4. General Methodology

OELMs are applied within the OEA methodology as discussed in Section 2.B. OELMs are used to estimate the decrement to operational effectiveness due to collateral effects on personnel or requirements placed on personnel or military units by a CBRN event. They are separated into four categories as defined in Chapter 3: MCMs, NMCMs, RAs, and IXs. One challenge in estimating the impact of OELMs on individual and unit operational effectiveness is the number and types of multipliers. Each type of countermeasure, RA, and IX has the potential to impact unit operational effectiveness differently, and each OELM category and subcategory may require a unique modeling approach. The current intent of the OELM methodology is that the modeling efforts should not vary by class; however, further investigation may identify a requirement for varying approaches within classes as well.

To illustrate the need for various modeling approaches, consider the following: Antibiotic prophylaxis may cause allergic reactions in some fraction of the population, rendering these individuals unable to perform the mission for some duration, while others will suffer only mild effects or no effects at all. The gloves required by a MOPP 4 posture, on the other hand, will likely reduce, but not eliminate, the operational effectiveness of those who wear them during mission tasks due to a decrease in dexterity and range of motion. Finally, decontamination tasks require the full attention of an unaffected soldier, eliminating his ability to contribute to the unit's primary mission (except when decontamination is the principal mission of the unit), but only for as long as he is required to perform this task. This chapter lays out a suggested general procedure for evaluating OELMs. As the research progresses, separate approaches will likely be required for each category, and unique parameters will likely be required for each distinct example.

1. General Approach

The goal of the OELM approach is to quantitatively define each OELM so that it can be incorporated into the OEA methodology—specifically, to estimate the OELM impact is Step 3 of the OEA methodology.

Modeling the effects of each OELM class is based on three sets of parameters:

- Number of individual personnel impacted by the OELM;

- Duration of impact; and
- Residual operational effectiveness (or the associated WIA SL, which can be used to estimate the associated operational effectiveness) of those military units impacted by the OELM. Operational effectiveness may vary over time and therefore may be written as a function of time.

The number of personnel impacted by the OELM will be presented as either (1) a ratio of impacted personnel to those evaluated as WIAs; (2) a fraction of the PAR or PE-PAR; or (3) a static number based on personnel requirements. It is possible for effectiveness to be represented as a spectrum over time. For example, an individual could wear an article of protective equipment for 4 hours, rending him 25% effective during this period of time, and then he could remove that equipment, returning him to 100% effective. Using the OELM categories discussed in Chapter 2, the data required to model losses due to operational effectiveness loss multipliers (LOELMs) and preliminary estimates of the scale of these values are outlined in Table 2.

Table 2. Four OELM Categories and Associated Parameters

	MCMs	NMCMs	RAs	IXs
Examples	MMCM-Vaccine	NMCM-IPE	Decontamination Buddy Aid	CS
Number impacted ($I_{\#}$)	Fraction of impacted vs. PAR, PE-PAR or WIA (depending on the MCM)	Fraction of impacted vs. PAR, PE-PAR or WIA (depending on the NMCM)	Ratio of Un:WIA	Ratio of Un:WIA
Duration of impact	Hours to weeks	Hours to days	Hours to days	Days to mission end
ROE	Partially effective to operationally ineffective (casualty)	Partially effective to operationally ineffective	Operationally ineffective	Partially effective to operationally ineffective
Return to Duty (RTD)	Protracted, possibly time-limited RTD	Full RTD	Full RTD	Possible, dependent on severity of stress
Description	Administration of the MCM reduces the number of casualties but may cause side effects that reduce operational effectiveness of the PAR in which they are administered. *(The side effects will not reduce the PAR to whom the OELM is administered except for OELMs for which specific medical exemptions are noted.)*	Use of the NMCM may reduce the number of casualties but may also cause side effects that reduce operational effectiveness of the PAR in which they are administered. *(The side effects will not reduce the PAR who uses the NMCM.)*	Performance of RA on casualties and SNCs to restore them to duty or remove them from the theater reduces the operational effectiveness of the unit while RA is performed.	Manifestation of CS in the PAR can vary widely in severity depending on the causative CBRN effect and thus vary its impact on operational effectiveness of individuals and the unit.

Once the input values to the OELM approach have been established, they become the parameters for Step 1 of the OEA methodology (select OEA parameters for use in HRIP and OEA methodology). Several notional examples of OELM classes with corresponding example subclasses are shown in the next section.

Step 2 of the OEA methodology estimates the numbers of WIA and fatalities due to the direct effects of the CBRN event using the HIRP methodology.

Estimating the resulting effectiveness due to each of these OELM subclasses is Step 3 in the OEA methodology (estimate the impact of OLEMs on the unit's operational effectiveness). The specifics of this step are dependent upon the nature of the subcategory or class under examination.

An example might be operational effectiveness as it is influenced by donning different IPE in progressively more protective MOPP status over time. Putting a unit into the subclass represented by MOPP Level 1—wearing the overgarment—could result in some operational effectiveness loss for a period of time. Having portions of the unit progressing to MOPP Level 3—wearing the mask and hood along with boots—would result in additional losses for some individuals or fraction of the military unit. Finally, moving some or all the unit to MOPP Level 4—which requires wearing gloves—would result in additional losses of operational effectiveness. Each set of subclasses (i.e., MOPP Levels 1, 3, or 4) represents the progression of effects in terms of a single class (MOPP) of subcategory IPE at a point (or multiple points) in time.

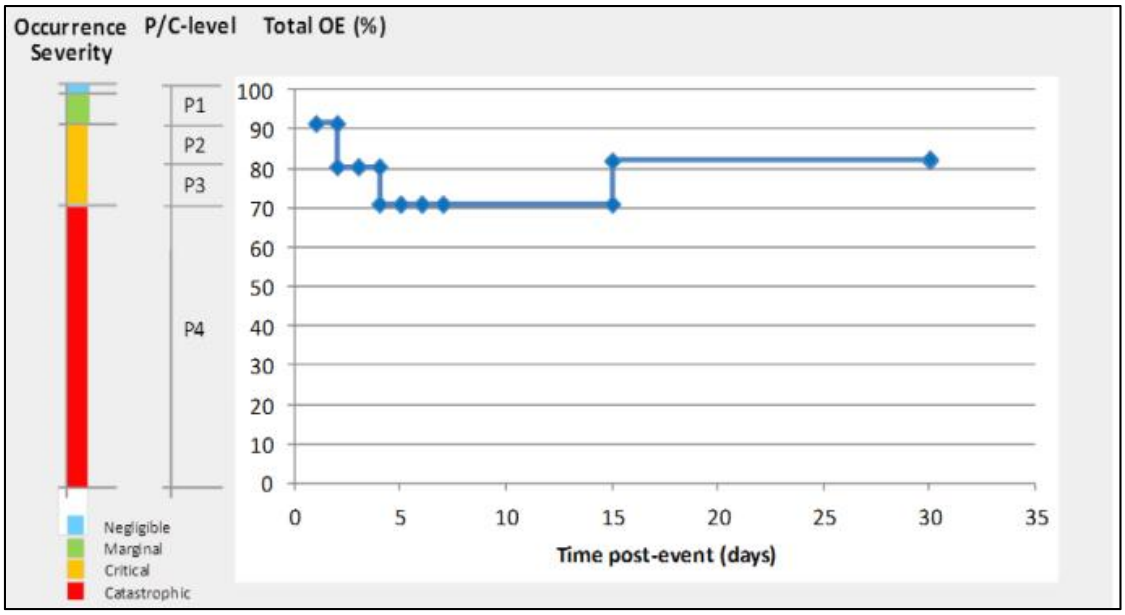
Classes or subclasses of MMCMs, on the other hand, can influence operational effectiveness through the generation of SNCs, WIAs, or fatalities: that is, through the manifestation of symptoms at varying SLs. For example, administration of a specific antibiotic (subclass) given as PEP (class) may result in losses due to manifesting mild symptoms in some portion of the PAR while some other portion of the PAR manifests severe symptoms at another time. For each portion of the PAR, the symptoms are present for different durations and can begin at different times. A residual operational effectiveness is associated with each SL.

The total operational effectiveness of the unit is then calculated in Step 4 by summing the operational effectiveness across all applicable OELM classes with the operational effectiveness of the unit due to the direct effects of the CBRN event.

Step 5 of the OEA methodology (graphically determine the quantitative operational effectiveness of the unit over time) should be followed as outlined in *Operational Effectiveness Analysis*.[66] The introduction of OELMs does not change the need or the ability to

[66] Zirkle et al., *OEA.*

graph operational effectiveness. Figure 5 provides a notional representation of operational effectiveness over time for a notional brigade combat team.



Source: Zirkle et al., *OEA*, 22.

Figure 5. OEA Graphical and Quantitative Assessment

It may be necessary to evaluate multiple OELMs simultaneously on a given set of individuals or fraction of a unit. To do so, the user must decide whether the collateral effects are independent of one another and if so, whether they are cumulative or hierarchical. For example, for an individual who is manifesting mild symptoms due to antibiotic PEP and who is also degraded due to wearing MOPP Level 4 equipment, the effect of the symptoms may be assumed to be independent and cumulative. In such cases, the total operational effectiveness due to the OELMs for those individuals or fraction of a unit is calculated simply by summing the operational effectiveness for each individual OELM class (or subclass) that applies to those individuals in Step 3.

On the other hand, an example of independent and hierarchical collateral effects can be seen where an individual who is administering buddy aid is lost to his unit for the time that he is not performing his assigned mission. If his ability to provide buddy aid is degraded due to wearing IPE, that degradation is unimportant in the estimation of his operational effectiveness because he is already a loss to the unit overall. In such cases, the user should select the minimum operational effectiveness at each point in time.

Additional investigation is required to determine how to combine multiple OELMs when they are not independent.

2. Data Sources

To identify current protocols following a CBRN attack, the research team relied upon military doctrine, including Army Field Manuals (FMs); Naval Tactics, Techniques, and Procedures (NTTP); Marine Corps Reference Publications (MCRPs); Air Force tactics, techniques, and procedures (TTP); military standard operating procedures (SOPs); and multi-Service tactics, techniques, and procedures (MTTP). The research team also consulted guidance from the United States Medical Research Institute of Infectious Disease (USAMRIID), the United States Army Medical Research Institute of Chemical Defense (USAMRICD), and other institutions. Finally, the research team considered values captured in previous government and academic research and modeling efforts.

Whenever possible, the research team used the most recent iteration of a given publication to ensure that the latest data are captured. Civilian responses to CBRN incidents were also taken into account, though at a lower priority since the procedures for a civilian population may be dramatically different than the procedures for a military population. When academic sources were considered, the research team focused on those papers published in a peer-reviewed journal.

This collection of data sources sufficed for the notional classes discussed in this paper and will be used for future efforts that develop OELMs for specific CBRN events. For some future efforts, data may be wholly unavailable, the research team request meetings with appropriate subject matter experts (SMEs) to ascertain values for the desired OELM parameters.

3. Limitations

The principal challenge in this research is the dearth of data available concerning human reactions to CBRN events, which are historically infrequent and difficult to safely simulate. The available data are often based on civilian incidents or conventional weapons (such as explosives), which requires the research team to estimate the scaling and relevance required to translate this information to a CBRN event.

The investigation of OELMs is further complicated by the varied and distinctive MCMs, triggered RAs, and resulting IXs, necessitating a unique research line for each category and each class within the categories. For instance, the most applicable data for military decontamination are found in FMs and other protocol documents, while CS is best researched though academic literature and case studies. As a proof of concept, the research team has conducted research into three specific OELM examples to demonstrate the proposed methodology (or how the proposed parameter values might be developed in the case of CS). Chapter 5 discusses these illustrative examples and includes a full notional integration for two examples into the OEA methodology.

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5. Illustrative Examples

The research team conducted research on three illustrative examples as a proof-of-concept:

- MMCM anthrax antibiotic PEP, which will be used to illustrate MCMs;
- decontamination, which will be illustrative of RAs; and,
- CS, which will represent IXs.

These examples also illustrate three different levels of development and maturity: decontamination estimates are based on well-developed protocols, while CS is largely notional at this stage. An anthrax MMCM falls in the middle, with established administration protocols but with side effects and operational effectiveness losses based on academic research and experimental data. Follow-on research into other OELM classes will likely require similar combination of established medical and DOD protocols and guidance derived from academic research and experimental results.

A. Medical Materiel Countermeasure (MMCM): Anthrax Antibiotic Post-Exposure Prophylaxis (PEP)

Anthrax is a non-contagious disease caused by the spore-forming bacterium *Bacillus anthracis*, which produces toxins that kill cells and cause fluid to accumulate in the body's tissues. Humans typically contract the disease by handling contaminated hair, hides, and the flesh of cattle, sheep, goats, and horses. Naturally occurring anthrax incidents in the United States are extremely rare, with one or two cases reported annually.[67] Aerosolized *B. anthracis* is considered to be a likely candidate for a bioterrorism incident due to the small number of spores required for infection, the high mortality rate of anthrax, and the potential ease of dissemination.[68] This type of attack would likely produce large numbers of inhalational anthrax cases and will be the assumed method of

[67] See "Centers for Disease Control and Prevention, 'Anthrax: Technical Information,'" last updated August 26, 2009, http://www.cdc.gov/nczved/divisions/dfbmd/diseases/anthrax/technical.html.

[68] Jeffrey W. Runge, "Emergency Department Preparedness for Bioterrorism" (briefing, Annual Conference of the Emergency Department Practice Management Association (EDPMA) Solutions Summit XI, Las Vegas, NV, May 14–16, 2008), http://www.hsdl.org/?abstract&doc=101653&coll=limited.

delivery for this paper. Inhalation anthrax generally has an incubation period of between 1 and 6 days[69] and a mortality rate of 100% if left untreated.[70]

The current DOD policy in response to a potential *B. anthracis* attack is immediate PEP (pre-symptom onset) regardless of whether an individual was previously vaccinated. The preferred antibiotic prophylaxes are ciprofloxacin hydrochloride (Cipro) and doxycycline hyclate (Doxy), which are taken orally for at least 60 days.[71] Other anti-biotics can be prescribed in lieu of, or in addition to, ciprofloxacin or doxycycline.[72] As discussed in detail below, gastrointestinal symptoms, including nausea, vomiting, diarrhea, and abdominal pain, were commonly reported. Therefore, for this illustrative example, the research team concentrated on doxycycline, which is one of the two most commonly used antibiotic prophylaxes, and focused only on the gastrointestinal symptoms associated with doxycycline use.

1. Recommended Values

Table 3 shows the recommended LOELM factors for anthrax PEP with doxycycline.

Table 3. Recommended OELM Parameters for Anthrax PEP with Doxycycline Hyclate

	Anthrax Doxycycline PEP: Gastrointestinal Symptoms	
Criteria	**Anthrax Doxycycline PEP Mild Symptoms**	**Anthrax Doxycycline PEP Moderate Symptoms**
Number impacted	29.0% * PE-PAR	14.3% * PE-PAR
Duration of impact	SNC at SL 1: 60 days starting 1 day after initial PEP administration	WIA at SL 2: 60 days starting 1 day after initial PEP administration
ROE (λ)	0.90	0

69 Rare cases and animal trials have reported incubation periods as long as 100 days. See Zygmunt Dembek, ed., *Medical Management of Biological Casualties Handbook*, 7th ed. (Fort Detrick, MD: United States Medical Research Institute of Infectious Disease (USAMRIID), September 2011), 27. http://www.usamriid.army.mil/education/bluebookpdf/USAMRIID%20BlueBook%207th%20Edition%20-%20Sep%202011.pdf.

70 Carl A. Curling et al., *Technical Reference Manual: NATO Planning Guide for the Estimation of Chemical, Biological, Radiological, and Nuclear (CBRN) Casualties, Allied Medical Publication 8(C)*, Document D-4082 (Alexandria, VA: Institute for Defense Analyses (IDA), August 2010), 201.

71 The recommended dosage for ciprofloxacin is 500 mg orally twice a day. The recommended dosage for doxycycline is 100 mg orally twice a day. See Jenifer Gordon Wright et al., "Use of Anthrax Vaccine in the United States: Recommendations of the Advisory Committee on Immunization Practices (ACIP), 2009." *Mortality and Morbidity Weekly Report (MMWR) Recommendations and Reports* 59, no. RR-6 (July 23, 2010): 16, http://www.cdc.gov/mmwr/pdf/rr/rr5906.pdf.

72 Dembek, *Medical Management*, 29–30.

2. Approach

Doxycycline is an antibiotic in the tetracycline family and is prescribed for a number of bacterial illnesses, including urinary tract infections, respiratory infections, anthrax, and plague. Reactions to doxycycline, like many antibiotics, are gastrointestinally focused. To begin cataloging the side effects for use in the OEA methodology, IDA conducted a literature review of relevant safety studies for doxycycline. Using the symptom severity definitions from HRIP, the research team mapped each antibiotic reaction symptom to an appropriate SL (1 to 3). Table 4 shows the gastrointestinal symptoms and the resulting classifications.

Table 4. Doxycycline Gastrointestinal Symptom Severity

SL 1	SL 2	SL 3
Abdominal pain	Diarrhea	
Constipation	Severe gastro-intestinal problems	
	Vomiting	

The majority of the studies with safety information for doxycycline found by the IDA research team had usually been conducted on populations with a pre-existing bacterial infection—usually chlamydia—and were intended to compare relative efficacy and safety of doxycycline with one or more alternative antibiotics. The study participants for doxycycline had a mean age in their twenties,[73] likely correlated to the disease being treated. Table 5 presents the gastrointestinal symptoms derived from studies in which doxycycline was used as a treatment (vs. prophylaxis). The typical dose administered in these studies was 100 mg twice daily for seven days. The percentages shown in the table may indicate overlap or synergism of symptoms in patients, or may be distinct

[73] Mean age of study participants were 26.2, 23.6, and 24.7. Studies reflecting these median ages were as follows:

26.2: A. Nilsen et al., "A Double Blind Study of Single Dose Azithromycin and Doxycycline in the Treatment of Chlamydial Urethritis in Males," *Genitourinary Medicine* 68, no. 5 (1992): 326, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1195989/pdf/genitmed00035-0047.pdf.

23.6: E. M. Thorpe Jr. et al., "Chlamydial Cervicitis and Urethritis: Single Dose Treatment Compared with Doxycycline for Seven Day in Community Based Practises," *Gemotourinary Medicine* 72, no. 2 (1996): 95, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1195615/pdf/genitmed00008-0019.pdf.

24.7: W. M. McCormack et al., "Daily Oral Grepafloxacin vs. Twice Daily Oral Doxycycline in the Treatment of *Chlamydia trachomatis* Endocervical Infection," *Infectious Diseases in Obstetrics and Gynecology* 6, no. 3 (1998): 112, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1784789/pdf/9785106.pdf.

presentations; therefore, the percentage values for each symptom severity should be considered an upper bound.

Table 5. Doxycycline Treatment Gastrointestinal Symptom Severity Percentages

SL 1	Nilsen[a]	Thorpe[b]	McCormack[c]	Tan[d]
Abdominal Pain	3.13%	4.10%	2.24%	41.4%
Constipation	1.56%	nr	nr	nr
Nausea	6.25%	22.05%	15.24%	34.5%
SL 2	Nilsen	Thorpe	McCormack	Tan
Diarrhea	3.13%	4.10%	1.79%	nr
Vomiting	nr	4.10%	8.97%	27.6%

The literature review also found studies in which doxycycline was used as a prophylaxis. The doses were typically 100 mg and ranged from 4 days up to 6 months. Table 6 presents the gastrointestinal symptoms found in these studies. Only studies addressing two or more of the gastrointestinal symptoms are captured in the table. One study captured only one gastrointestinal symptom: Israeli Air Force personnel in Rwanda, in which 25% reported abdominal pain.[74] Studies that focused on children were excluded.

The IDA research team examined two approaches for estimating the percentage of personnel affected by doxycycline. In the first, the IDA research team looked for dominant symptoms at each SL, assuming that these dominant symptoms are most likely to be experienced by the population and therefore representative of the percentage of the population expected to experience symptoms at that SL. For these dominant symptoms, the team looked at two extreme cases for the relationship between symptoms within the same SL: either they were completely independent of one another (individuals experience either symptom one or symptom two but not both) or else they were tightly bound with one another (individuals suffering from one symptom always had the other). In the first case, the incidence of the SL would be the sum of the symptom incidences. In the second case, the incidence of the SL would be identical to the incidence of the prevalent of the symptoms. The first case represents a highest possible value for the estimate for the SL incidence, while the second case represents the lowest possible value for the estimate. In the absence of any additional information regarding the relationship between the symptoms, the research team took the average of these two values as the estimate for the incidence of that SL.

74 A. Shamiss et al., "Mefloquine Versus Doxycycline for Malaria Prophylaxis in Intermittent Exposure of Israeli Air Force Aircrew in Rwanda," *Aviation Space and Environmental Medicine* 67, no. 9 (1996): 873, http://www.ncbi.nlm.nih.gov/pubmed/9025805.

Table 6. Doxycycline Prophylaxis Gastrointestinal Symptom Severity Percentages

	Studies								
	Andersen[a] Kenya	Ohrt[b] Indonesia	Arthur[c] Thailand	Pages[d] Chad	Pages[d] Chad	Shanks[e] Cambodia	Shanks[e] Papua New Guinea	Taylor[f] Indonesia	Sonmez[g] Afghanistan
Number in study	55	67	119	133	142	1,200	nr	75	507
SL 1									
Abdominal pain	89.1%	11.9%	nr	Nr	nr	nr	nr	4.0%	5.9%
Nausea	nr	4.5%	16.7%	5.3%	16.2%	35%	8.0%	6.0%	8.1%
SL 2									
Diarrhea	16.4%	6.0%	nr	19.5%	18.3%	nr	nr	7.0%	35.8%
Vomiting	10.9%	1.5%	4.4%	Nr	nr	5%	2.0%	nr	2.0%

Note: nr – not reported.

Sources:

[a] S. L. Andersen et al., "Successful Double-Blinded, Randomized, Placebo-Controlled Field Trial of Azithromycin and Doxycycline as Prophylaxis for Malaria in Western Kenya," *Clinical Infectious Diseases* 26, no. 1 (1998): 150, http://www.ncbi.nlm.nih.gov/pubmed/9455524.

[b] Colin Ohrt et al., "Mefloquine Compared with Doxycycline for the Prophylaxis of Malaria in Indonesian Soldiers: A Randomized, Double-Blind, Placebo-Controlled Trial," *Annals of Internal Medicine* 126, no. 12 (1997): 968, http://www.ncbi.nlm.nih.gov/pubmed/9182474.

[c] James D. Arthur et al., "A Comparative Study of Gastrointestinal Infections in United States Soldiers Receiving Doxycycline or Mefloquine for Malaria Prophylaxis," *American Journal of Tropical Medicine and Hygiene* 43, no. 6 (1990): 610, http://www.ncbi.nlm.nih.gov/pubmed/2267964.

[d] Frédéric Pagès et al., "Tolerability of Doxycycline Monohydrate Salt vs. Chlorquine-proguanil in Malaria Chemoprophylaxis," *Tropical Medicine and International Health* 7, no. 11 (2002): 923, http://www.ncbi.nlm.nih.gov/pubmed/12390596.

[e] The Cambodia data were captured at three times during the study at 2, 4, and 8 months. The initial values were high at the 2-month mark—45% for nausea and 28% for vomiting—and changed over time. These values were explained by the study's authors as "probably due to greater compliance with regard to advice concerning the ingestion of medication with food …" Therefore, the study team captured the values at 4 months. See G. Dennis Shanks et al., "Doxycycline for Malaria Prophylaxis in Australian Soldiers Deployed to United Nations Missions in Somalia and Cambodia," *Military Medicine* 160, no. 9 (1995): 444, http://www.ncbi.nlm.nih.gov/pubmed/7478027.

[f] Walter R. Taylor et al., "Tolerability of Azithromycin as Malaria Prophylaxis in Adults in Northeast Papua, Indonesia," *Antimicrobial Agents and Chemotherapy* 47, no. 7 (2003): 2200, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC161858/.

[g] Alper Somnez et al., "The Efficacy and Tolerability of Doxycycline and Mefloquine in Malaria Prophylaxis of the ISAF [International Security and Assistance Force] Troops in Afghanistan," *Journal of Infection* 51, no. 3 (2005): 256, http://www.ncbi.nlm.nih.gov/pubmed/16230223.

Nausea and abdominal pain were the most commonly reported mild symptoms (SL 1). Looking at the data for doxycycline as a prophylaxis, the research team calculated that abdominal pain was reported on average in 27.7% of the population and nausea in 12.5%; based upon the estimation scheme described above, the research team determined that 20.1% of those who take doxycycline would be classified as SL 1. Similarly,

diarrhea and vomiting were the most commonly reported moderate symptoms (SL 2). Again, using data for doxycycline as a prophylaxis, the research team calculated that diarrhea was reported on average in 17.2% of the population and vomiting in 4.3% for vomiting, leading to an estimated 10.8% of those who take doxycycline would be classified as SL 2.

Because of the variation between studies, the wide range of reported symptoms, and the dependent nature of many of these symptoms, the research team considered an alternative method for estimating the number of individuals who experience adverse reactions following administration of prophylaxis. Specifically, other studies were examined that reported only non-specific gastrointestinal symptoms, with reporting ranging from 17% to 50%.[75] Two of these studies further classified these non-specific symptoms as either mild or moderate. Mild symptoms were those that did not interfere with daily activity, while moderate symptoms did. Table 7 presents the results from these two studies. The IDA research team chose to use the values derived from this approach, which gave values similar to those derived from the first approach (29.0% vs. 20.1 for SL 1 and 14.3% vs. 10.8% for SL 2).

[75] Non-specific gastrointestinal symptoms were reported in five studies with a mean rate of 32%. Studies used to evaluate the rate of non-specific gastrointestinal symptom reporting were as follows:

17.0%: Mark R. Wallace et al., "Malaria Among United States Troops in Somalia," *American Journal of Medicine* 100, no. 1 (1996): 54, http://www.ncbi.nlm.nih.gov/pubmed/8579087.

24.4%: Karl H. Rieckmann et al., "Recent Military Experience with Malaria Chemoprophylaxis," *Medical Journal of Australia* 158, no. 7 (1993): 448, http://www.ncbi.nlm.nih.gov/pubmed/8469191.

34.6%: J. L. Sánchez et al., "Mefloquine or Doxycycline Prophylaxis in US Troops in Somalia," *The Lancet* 341, no. 8851 (1993): 1021, http://www.ncbi.nlm.nih.gov/pubmed/8096898.

35.5%: Christine Korhonen et al., "Self-Reported Adverse Events Associated with Antimalarial Chemoprophylaxis in Peace Corps Volunteers," *American Journal of Preventive Medicine* 33, no. 3 (2007): 197, http://www.ncbi.nlm.nih.gov/pubmed/17826578.

50.1%: Patricia Schlagenhauf et al., "Tolerability of Malaria Chemoprophylaxis in Non-immune Travellers to sub-Saharan Africa: Multicentre, Randomised, Double Blind, Four Arm Study," *British Medical Journal* 327, no. 7423 (2003): 1080, http://www.ncbi.nlm.nih.gov/pubmed/14604928.

Table 7. Doxycycline Prophylaxis Nonspecific Gastrointestinal Symptom Severity Percentages

	Studies		
	Schlagenhauf[a] Sub-Saharan Africa	Korhonen[b] Varied Countries	Average
Number in study	153	228	
Mild (SL 1)	41.8%	16.2%	29.0%
Moderate (SL 2)	9.2%	19.3%	14.3%

[a] Schlagenhauf et al., "Tolerability of Malaria Chemoprophylaxis in Non-immune Travellers to sub-Saharan Africa: Multicentre, Randomised, Double Blind, Four Arm Study." *British Medical Journal* 327, no. 7423 (2003): 1080. http://www.ncbi.nlm.nih.gov/pubmed/14604928.

[b] Korhonen et al., Self-Reported Adverse Events Associated with Antimalarial Chemoprophylaxis in Peace Corps Volunteers." *American Journal of Preventive Medicine* 33, no. 3 (2007): 197. http://www.ncbi.nlm.nih.gov/pubmed/17826578.

Severe symptoms (SL 3) were not consistently observed in the studies identified by the research team, and so were not included. Although study participants did occasionally withdraw from the studies, the reasons included misdiagnosis of the disease the prophylaxis was intended to prevent, protocol violations, and skin rashes which did not appear to be drug related. A few studies noted non-specific adverse events or did not give any reasons for the withdrawals. Three studies specifically stated that the prophylaxis was well-tolerated and did not result in side-effects of a severity to require discontinuation.[76]

Little information was found on the onset time for gastrointestinal symptoms. The research team chose to use the max serum time of 2.6 hours[77] as a lower bound for symptom onset but rounded this value to 1 day since OELM is calculated on a daily basis. Doxycycline is given as a 60-day course following an anthrax attack. The research team assumes that the medication would continue to be taken throughout the 60 days regardless of side-effect symptoms.

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[76] Rieckmann, et al., "Recent Military Experience with Malaria Chemoprophylaxis," 448; S. L. Andersen et al., "Successful Double-Blinded, Randomized, Placebo-Controlled Field Trial of Azithromycin and Doxycycline as Prophylaxis for Malaria in Western Kenya," *Clinical Infectious Diseases* 26, no. 1 (1998): 148, http://www.ncbi.nlm.nih.gov/pubmed/9455524; and James D. Arthur et al., "A Comparative Study of Gastrointestinal Infections in United States Soldiers Receiving Doxycycline or Mefloquine for Malaria Prophylaxis," *American Journal of Tropical Medicine and Hygiene* 43, no. 6 (1990): 610, http://www.ncbi.nlm.nih.gov/pubmed/2267964.

[77] Aqua Pharmaceuticals, LLC, "Monodox® Doxycycline Monohydrate Capsules, Rx Only," revised January 2012, accessed December 30, 2014, http://www.aquapharm.com/pdf/MonodoxPI2012Jan.pdf.

3. Assumptions

The following assumptions were made based on the best available data and modeling necessities:

- All gastrointestinal symptoms result from prolonged use of doxycycline.
- Given the potential disease associated with anthrax exposure, the gastrointestinal symptoms are not severe enough to result in the discontinuation of doxycycline's use.
- While several possible side effects (and adverse reactions) result from the use of doxycycline for prolonged periods, for this illustrative example, only the gastrointestinal symptoms are modeled.
- The threshold for seeking medical attention and becoming a WIA is set at SL 2. As a result, those individuals at SL 1 are classified as SNC.
- The side effects of the doxycycline cease immediately after the prophylactic antibiotic course is discontinued. This immediate cessation is likely an underestimation of the duration of the side effects, but it was useful for illustrative purposes due to lack of additional information on the duration of the effects.

4. Results

The research team calculates the operational effectiveness based on the number of impacted: the vaccinated PAR (or the PE-PAR for this example), the duration of the impact, and the ROE resulting from the vaccination. Therefore, if 1,000 troops (PE-PAR) are given doxycycline as an anthrax PEP on day 3, then, at day 4, there will be two additional cohorts that are assumed to last for the duration of the PEP administration (60 days): (1) those whose symptoms are moderate and result in them becoming WIA_Cs and thereby ineffective and (2) those whose symptoms are mild and result in them becoming SNC_C and thereby partially effective. Thus,

$$WIA_{C,Doxy}(t) = \begin{cases} 0 \; if \; t < 4 \\ 14.3\% * \textit{PE-PAR} if \; t \geq 4, < 64 \\ 0 \; if \; t \geq 64, \end{cases}$$

$$SNC_{C,Doxy}(t) = \begin{cases} 0 \; if \; t < 4 \\ 29.0\% * \textit{PE-PAR} if \; t \geq 4, < 64 \\ 0 \; if \; t \; \geq 64, \end{cases}$$

The unaffected cohort (Un) is then calculated as

$$Un_{Doxy}(t) = PE\text{-}PAR - WIA_{C,Doxy}(t) - SNC_{C,Doxy}(t).$$

Thus, the operational effectiveness of the individuals who received the MMCM and who become operationally ineffective (OE-IE) or partially effective (OE-PE), and those who remain fully operationally effective (OE-FE) are estimated as follows:

$$OE\text{-}IE_{Doxy}(t) = WIA_{C,Doxy}(t) * (\lambda_{WIA}),$$

$$OE\text{-}PE_{Doxy}(t) = SNC_{C,Doxy}(t) * (\lambda_{SNC}),$$

$$OE\text{-}FE_{Doxy}(t) = Un_{Doxy}(t) * (\lambda_{Un}) = Un_{Doxy}(t),$$

where λ_{WIA}, λ_{SNC}, and λ_{Un} are the ROEs for WIA, SNC and the unaffected cohorts, respectively. The unit's operational effectiveness following administration of doxycycline then is given by the following:

$$OE_{Doxy}(t) = OE\text{-}FE_{Doxy}(t) + OE\text{-}PE_{Doxy}(t) + OE\text{-}IE_{Doxy}(t).$$

5. Incorporation into the OEA Methodology

Assuming that 1,000 troops received the anthrax PEP and experienced no adverse reactions other than gastrointestinal symptoms and assuming that no other event occurred to cause additional casualties, the personnel status over time is as shown in Table 8.

Table 8. Calculation for Notional Anthrax PEP Example

	Duration Post-Event (Days) – Casualty Threshold SL 2								
Status	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**15**	**30**
Total population	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Un	1,000	1,000	1,000	433	433	433	433	433	433
SNC (SL 1)	0	0	0	290	290	290	290	290	290
WIA (SL 2)	0	0	0	143	143	143	143	143	143
WIA (SL 3)	0	0	0	0	0	0	0	0	0
OE-IE	0	0	0	0	0	0	0	0	0
OE-PE	0	0	0	261	261	261	261	261	261
Total OEA	**1,000**	**1,000**	**1,000**	**828**	**828**	**828**	**828**	**828**	**828**

In this case, the antibiotic PEP results in mild gastrointestinal symptoms in 290 individuals who experience a 10% degradation for 60 days (or are 90% partially effective) and 143 individuals who become WIAs and are therefore a loss to their unit and ineffective for 60 days until symptoms cease. The remainder of the unit is unaffected and operationally effective.

6. Way Forward

MMCMs cause mild side effects and adverse reactions. The example in this section illustrates two potential side effects resulting from the administration of doxycycline as an antibiotic PEP and how these adverse reactions might be modeled using the OELM methodology. Additional side effects and adverse reactions from the antibiotic may result in further degradation of a unit's operational effectiveness and therefore also need to be considered. Likewise, additional MMCMs and their resultant side effects and adverse reactions as well as their impact on operational effectiveness will be investigated in further research efforts.

B. Response Activity (RA): Decontamination of Biological Agent

Decontamination is "the process of making any person, object, or area safe by absorbing, destroying, neutralizing, making harmless, or removing chemical or biological (CB) agents, or by removing radioactive material clinging to or around it."[78] Forces can implement decontamination for a number of different items, including all forces, patients (both ambulatory and litter borne), and equipment. A Brigade Combat Team (BCT), as part of its directed tasks, might be asked to "remediate hazards remaining from the release of CBRN hazards and radiological fallout, as well as provide decontamination support."[79] Patient decontamination is a response activity triggered by the need for aid and consists of those individuals who are a loss to their unit because they are pulled from their regular duty to perform duties at a decontamination station.

The IDA research team selected a small subset of tasks[80] that might be performed by a unit within the BCT during decontamination of biological agent (potentially in support of a larger dedicated CBRN decontamination unit) for focus within the illustrative example. Decontamination activities examined here include cutting and removing patient protective outer garments and swabbing the skin with a specialized decontamination solution. Additional tasks include moving severely injured patients on and off the litters.

For the duration of decontamination procedures, the individuals performing decontamination are considered operationally ineffective. Modeling of decontamination is based the latest military protocols and best practices.

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78 Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, 63.

79 U.S. Army, *Brigade Combat Team*, FM 3-90.6 (Washington, DC: Headquarters, Department of the Army, September 2010), 4-3, http://armypubs.army.mil/doctrine/DR_pubs/dr_a/pdf/fm3_90x6.pdf.

80 In the parlance of this methodology, these tasks would be subclasses under the biological decontamination class of the RA category; see Section 3.B of this paper.

1. Recommended Values

Table 9 shows the recommended LOELM factors for decontamination.

Table 9. Recommended LOELM Factors for Decontamination

Criteria	If All Ambulatory (SL 3 = 0)	If Mix of Ambulatory and Litter Borne (SL 3 > 0, SL 2 + SL 1 + SL 0 > 0)	If All Litter Borne (SL 3 > 0, SL 2 + SL 1 + SL 0 = 0)
Number required (ρ)	5	29	36
Duration of decon (minutes)	$7 * \frac{SL(1) + SL(2)}{4}$	$7 * \frac{SL(1) + SL(2)}{2} + 14 * \frac{SL(3)}{2}$	$14 * \frac{SL(3)}{4}$
ROE (λ)	0	0	0

2. Approach

To develop the biological decontamination LOELM factors, the research team conducted an initial literature review of military manuals/procedures that focused on decontamination following a CBRN event and medical management of CBRN patients. Thorough consideration was given to the following field manuals: FM 3-11.5 *Multi-Service Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear Decontamination* (as well as FM 3-5, *NBC Decontamination*, which it supersedes); FM 8-284 *Treatment of Biological Warfare Agent Casualties*; and FM 4-02.7 *MultiService Tactics, Techniques and Procedures for Health Service Support in a Chemical, Biological, Radiological, and Nuclear Environment.* Preference was given to the most recent iteration of a particular FM since protocol is frequently updated to accommodate best practices and new equipment. The team also performed a wider search using the search engines Bing, Google, and Google scholar for key words.[81] Finally, USAMRIID's *Medical Management of Biological Causalities Handbook,* USAMRICD's *Medical Management of Chemical Casualties Handbook,* and the volume of the Army Surgeon General's *Textbook of Military Medicine* entitled *Medical Aspects of Biological Warfare* were considered.

In accordance with the guidance in these documents, the research team considered separate decontamination procedures for ambulatory and litter-borne patients. Most of the

[81] Search terms included the following: biological decontamination, patient decontamination, military guidance + decontamination, decontamination station, time required + patient decontamination, and chemical decontamination. The research team used a Boolean search methodology in which a plus sign (+) represents "and," requiring an Internet search engine to return only those webpages that have, for example, both "military guidance" AND "decontamination" in their text.

documentation on decontamination procedures recommends a team of eight or more non-medical individuals for a battalion aid station,[82] clearing station,[83] and unit or division levels of the Army.[84] A team of 20 or more non-medical personnel are required for field hospitals[85] as well as corps and field army operational units.[86] The most comprehensive examination of decontamination staffing found by the research team is shown in Figure 6, which presents the suggested eight-man teams at various stages of the decontamination procedure. Ambulatory patient decontamination needs are less well defined in the literature with most suggesting that "patients may be able to decontaminate themselves and assist with the decontamination of other ambulatory patients"[87] or that "some procedures can be done with one soldier, while others require more than one."[88] The only source to provide an estimate of the time required for decontamination was the USAMRICD's *Medical Management of Chemical Casualties Handbook*, which specifies a range of 8 to 20 minutes for a litter-borne patient.[89]

3. Assumptions

The following assumptions were made based on the best available data and modeling necessities:

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82 Headquarters, Department of the Army, Marine Corps Combat Development Command, Navy Warfare Development Command, and Headquarters, Air Force Doctrine Center, *Multi-Service Tactics, Techniques, and Procedures for Health Service Support in a Chemical, Biological, Radiological, and Nuclear Environment*, FM 4-02.7/MCRP 4-11.1F/NTTP 4-02.7/AFTTP 3-42.3 (Washington DC: Authors, July 2009), II-14, http://armypubs.army.mil/doctrine/dr_pubs/dr_a/pdf/fm4_02x7.pdf.

83 Headquarters, Department of the Army and Commandant, U.S. Marine Corps, *NBC Decontamination*, FM 3-5/MCWP 3-37.3 (Washington, DC: Authors, July 2000), 8-3, http://www.bits.de/NRANEU/others/amd-us-archive/fm3-5%2800%29.pdf.

84 Headquarters, Departments of the Army, the Navy, and the Air Force, and Commandant, Marine Corps, *Treatment of Biological Warfare Agent Casualties*, Army FM 8-284/Navy NAVMED P-5042/44-156/Air Force AFMAN (I) 44-156/Marine Corps MCRP 4-11.1C (Washington DC: Authors, July 2000), B-1, http://www.med.navy.mil/directives/Pub/5042.pdf.

85 Headquarters, Departments of the Army, the Navy, and the Air Force, and Commandant, Marine Corps, *NBC Decontamination*, 8-3.

86 Headquarters, Departments of the Army, the Navy, and the Air Force, and Commandant, Marine Corps, *Treatment of Biological Warfare Agent Casualties*, B-1.

87 Ibid., B-4.

88 Headquarters, Departments of the Army, the Navy, and the Air Force, and Commandant, Marine Corps, *NBC Decontamination*, 8-19.

89 U.S. Army Medical Research Institute of Chemical Defense (USAMRICD), *Medical Management of Chemical Casualties Handbook*, Third Edition (Aberdeen Proving Ground, MD: Chemical Casualty Care Division, July 2000), 192, http://www.operationalmedicine.org/TextbookFiles/mmccthirdedition jul2000.pdf.

Duty	*Minimal*	*Roller System*
Command and Control Cell		
Officer in charge.	1	1
Noncommissioned officer in charge. (May also serve as safety officer or another individual can be designated.)	1	1
Entry Control Point		
Entry control point security detail.	2 (optional)	
Augmentees to unload litter patients (2 teams of 4).	8	8 (4 if NATO litter carriers are used)
Security personnel to guard arrival point and perform pat-down search.	2 (optional)	2 (optional)
Road guides and lookouts (night operations).	3 (optional)	3 (optional)
Augmentee trained to use various contamination check tools.		1 (optional)
Triage and Emergency Medical Treatment Area (Warm Side)		
Senior health care NCO or other primary triage officer (PA, nurse).	1	1
Health care specialist to administer treatment.	1	1
Augmentees to serve as litter bearers (2 teams of 4 personnel).	8	
Litter Decontamination Area (Per Litter Lane)		
Augmentees who decontaminate the casualties and perform patient lifts. They wear TAP apron.	4	
Medical personnel.	1	1
Augmentee to clean litters.	1 (optional)	
Clothing removal area of roller system.		2
Body wash area of roller system.		2
Final check area of roller system.		1
Ambulatory Decontamination Area (Per Lane)		
Augmentee to assist patients.	1 (optional)	1 (optional)
Medical personnel.	1	1
Contamination Check Area		
Augmentee trained to use various contamination check tools.	1	
Hot Line Patient Reception (Members on the Clean Side of the Hot Line)		
Augmentees on clean side of the hot line who move litter patient across hot line.	2	2 (1 if NATO litter carriers are used)
Medic on clean side of hot line.	1	1
Total medical	5	5
Total augmentees/others	25–34	14–23
Total personnel for one work cycle	30–39	19–28
Note: This minimal staffing does not include MTF security detail.		

Source: Headquarters, Department of the Army, Marine Corps Combat Development Command, Navy Warfare Development Command, and Headquarters, Air Force Doctrine Center, *Multi-Service Tactics, Techniques, and Procedures for Health Service Support in a Chemical, Biological, Radiological, and Nuclear Environment,* FM 4-02.7/MCRP 4-11.1F/NTTP 4-02.7/AFTTP 3-42.3 (Washington DC: Authors, July 2009), V-37, http://armypubs.army.mil/ doctrine/dr_pubs/dr_a/pdf/fm4_02x7.pdf.

Figure 6. Suggested Minimal Staffing for a Decontamination Station

a. Biological and chemical decontamination procedures are interchangeable. Biological decontamination is less likely to occur than chemical decontamination due to the incubation period involved with biological agents. Nevertheless, there are unique situations in which biological decontamination will be performed: (1) if a unit is in the field when a positive, confirmed biological detection occurs, (2) an attack is perpetrated on a building with limited personnel movement (such

as a research building or personnel offices), or (3) a clearly overt attack occurs. FM 3-5, *NBC Decontamination,* thoroughly describes the decontamination procedures for chemical-, biological-, and nuclear-agent incidences. An examination of these procedures reveals virtually identical practices for the decontamination of chemical- and biological-agent patients. The research team has therefore concluded that chemical decontamination doctrine can be applied to biological decontamination.

b. **Individuals experiencing symptoms at SL 1, SL 2, and SL 3 will be decontaminated: SL 3 patients needing decontamination will be litter borne, and individuals at SL 1 and SL 2 will be ambulatory.** Using the definitions from HRIP, SL 3 patients are experiencing severe symptoms that may include difficulty walking or breathing. Such patients generally require hospitalization and would therefore likely be litter borne. SL 1 patients experience mild symptoms such as runny nose and headache, while SL 2 patients experience moderate symptoms, including mild fever and fatigue. It is not anticipated that patients suffering from moderate or mild symptoms would require a litter, so these patients will be considered ambulatory.

c. **Un (SL 0) personnel do not undergo decontamination.** While Un individuals have no signs or symptoms, there is still the possibility that they were exposed to the agent itself. Particularly for a biological agent attack, individuals who will eventually become casualties may remain at SL 0 for the duration of decontamination and manifest symptoms later. To fully estimate the number of SL 0 individuals who will require decontamination, more information regarding which of these individuals are within range of the agent attack is required. For example, when modeling an exposure cloud, those under the cloud but without sufficient exposure to result in symptoms might still be expected to undergo decontamination. For this illustrative example, the research team assumes that those without symptoms are outside the range of the CBRN event and therefore will not need to be decontaminated.

d. **Decontamination stations consist of four lanes. If both ambulatory and litter-borne patients are present, two lanes are dedicated to ambulatory patients and two to litter-borne patients; otherwise, all four lanes are devoted to a single patient type.** The research team has not found data at this time to indicate the number of decontamination lanes required based on the number of patients needing decontamination processing. FM 4-02.7 indicates that three lanes are available per compartment (or room used for decontamina-

tion) on Navy ships[90] and that the Air Force has an in-place decontamination tent that can accommodate four decontamination lanes.[91] Knowing that a four-lane decontamination setting is viable provides the research team a lower-bound for this initial look at decontamination. No data were found on the proportion of lanes dedicated to litter-borne and ambulatory patients when both types were present. The assumption of two each is based on presumed decontamination efficiency—that there will likely be more ambulatory patients than litter-borne patients but that those on a litter will take longer to decontaminate.

e. **A litter-borne patient takes 14 minutes to decontaminate.** This assumption is based on the USAMRICD decontamination range of 8 to 20 minutes, with a median value of 14 minutes.[92]

f. **An ambulatory patient takes seven minutes to decontaminate.** Without further data, the research team has assigned the ambulatory decontamination time as half that of the litter-borne patients. While much of the procedure is the same for ambulatory and litter-borne patients, in the ambulatory case, more clothing can be removed without cutting,[93] and no litter exchanges have to occur—both of which will likely speed the decontamination process.

g. **There is no overlap of patients in a decontamination lane.** When a patient enters a decontamination lane, this lane is considered busy and cannot be occupied until the decontamination process is complete. This assumption is a modeling simplifier and a product of data deficiency. If a time can be established for each stage of the decontamination station, this assumption could be relaxed.

h. **The non-medical personnel required at the decontamination station have a mission operational effectiveness of zero.** The personnel at the decontamination station cannot participate in the mission until decontamination is complete, giving them an ROE of zero.

i. **No personnel will be used for security.** This assumption is based on notion that security personnel, like the medical personnel, are intrinsic to the decontamina-

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90 Headquarters, Departments of the Army, the Navy, and the Air Force, and Commandant, Marine Corps, *Multi-Service Tactics, Techniques, and Procedures for Health Service Support in a Chemical, Biological, Radiological, and Nuclear Environment*, V-67.

91 Ibid., X-8.

92 U.S. Army Medical Research Institute of Chemical Defense (USAMRICD), *Medical Management of Chemical Casualties Handbook*, 192.

93 Headquarters, Departments of the Army, the Navy, and the Air Force, and Commandant, Marine Corps, *NBC Decontamination*, 4-11, 4-14, and 4-16.

tion station and are, therefore, not expected to come from the unit that faced the CBRN attack.

4. Results

The IDA research team calculated the reduction in the unit's operational effectiveness based on the residual operational effectiveness of the personnel involved in decontamination, the number of these personnel required, and the duration of their time away from their unit while they are involved in decontamination. Assumption h in the previous section assigned these personnel an ROE of zero.

Based on the literature review and the preceding assumptions, the number of personnel required for a decontamination station can be found using Figure 5. Three possible scenarios are considered: (1) all personnel requiring decontamination are ambulatory; (2) all personnel requiring decontamination are litter borne; or (3) a mix of ambulatory and litter-borne personnel require decontamination. Assumption d states that in the first two scenarios, all four decontamination lanes will be dedicated to a single type of patient, ambulatory or litter borne. In the third scenario, two lanes will be dedicated to ambulatory, and two will be dedicated to litter-borne patients. The total number of non-medical personnel required from the unit will therefore depend on the number of lanes designated to each type of patient. This calculation is provided in Table 10. Note that the entry, medical treatment, and hot-lane reception stations only require personnel if litter-borne patients are treated. If only ambulatory patients are present, no personnel are required at these positions.

Table 10. Number of Personnel Required in Decontamination Activities

	Personnel Required per Station		Total Personnel Required Based on Lane Allocation		
Station	Ambulatory	Litter	Four Ambulatory	Two Ambulatory/ Two Litter	Four Litter
Entry	0	8	0	8	8
Medical Treatment	0	8	0	8	8
Contamination Check	1	1	1	1	1
Hot-Lane Reception	0	2	0	2	2
			Personnel per Lane		
Decontamination	1	4	4	10	16
Total	2	23	5	29	35

Note: The first two columns indicate the number of individuals required to perform each function, depending on whether the decontamination lane processes ambulatory or litter-borne individuals. The remaining three columns indicate the number of individuals required to perform each function for four ambulatory lanes, a mix of two ambulatory and two litter-borne lanes, and four litter-borne lanes.

The amount of time the personnel will be away from their unit and involved in the decontamination will be a function of the number of decontamination lanes; the number of SL 1, SL 2, and SL 3 patient; and the amount of time it takes to decontaminate an individual. Given the assumption that patients do not overlap in a decontamination lane, a maximum of four patients—one per lane—can be in the station at any given time. The following equations provide the number of patients that will be seen in each lane during the decontamination procedure:

$$Let\ P_L = \begin{cases} \frac{SL(3)}{4}\ if\ SL(3) > 0\ and\ SL(1) + SL(2) = 0 \\ \frac{SL(3)}{2}\ if\ SL(3) > 0\ and\ SL(1) + SL(2) > 0 \\ 0\ if\ SL(3) = 0 \end{cases}$$

and

$$P_A = \begin{cases} \frac{SL(1)+SL(2)}{4}\ if\ SL(1) + SL(2) > 0\ and\ SL(3) = 0 \\ \frac{SL(1)+SL(2)}{2}\ if\ SL(1) + SL(2) > 0\ and\ SL(3) > 0 \\ 0\ if\ SL(1) + SL(2) = 0, \end{cases}$$

where P_L is the number of litter-borne patients decontaminated per lane and P_A is the number of ambulatory patients decontaminated per lane.

Based on assumptions e and f, the litter-borne patients need 14 minutes to complete decontamination and the ambulatory patients need 7 minutes to complete decontamination. The time (in days) during which those personnel are involved in decontamination ($T_{BioDecon}$) is given by the following:

$$T_{BioDecon} = P_L * \frac{14}{1440} + P_A * \frac{7}{1440}.$$

The number of personnel involved in decontamination over time ($N_{BioDecon}$) is determined by the following:

$$N_{BioDecon}(t) = \begin{cases} \rho\ if\ t_{D0} \le t \le T_{BioDecon}, \\ 0\ otherwise, \end{cases}$$

where t_{D0} is the start of another session of decontamination and ρ is the number of personnel required given the distribution of ambulatory and litter-borne patients. The unaffected cohort (Un) is then calculated as:

$$Un_{BioDecon}(t) = PE\text{-}PAR - N_{BioDecon}(t).$$

Thus, the operational effectiveness of the individuals who are involved in decontamination and thus become operationally ineffective (OE-IE), and those who

remain with their unit and are fully operationally effective (OE-FE) are estimated as follows:

$$OE\text{-}IE_{BioDecon}(t) = N_{BioDecon}(t) * \lambda_{BioDecon} = 0,$$

$$OE\text{-}FE_{BioDecon}(t) = Un_{BioDecon}(t) * \lambda_{Un} = Un_{BioDecon}(t),$$

where $\lambda_{BioDecon}$ and λ_{Un} are the REOs for biological decontamination and the unaffected cohorts, respectively. The unit's operational effectiveness is derived by the following:

$$OEA(t) = OE\text{-}FE_{BioDecon}(t) = Un_{BioDecon}(t).$$

5. Incorporation into the OEA Methodology

The OEA notional example from the *Operational Effectiveness Analysis* document was a hypothetical anthrax attack. Table 11 provides the HRIP output for the example.

Assuming that the attack was overt and that those who were exposed and will eventually manifest symptoms at SL 2 need to be decontaminated, the time required would be dependent only on the total SL 2, which is ambulatory only. These individuals are decontaminated at the onset of symptoms before being admitted to the medical system. Again, remember that for this illustrative example, all individuals who remain at SL 0 are assumed to be outside the contamination area and do not need to be decontaminated. Also, for the illustrative example, four lanes were assumed. Based on this assumption, the time and personnel required at each time step are provided in Table 12.

In this case, the decontamination procedure causes a negligible effect on the overall unit, with five individuals required to be away from their unit for less than 40 minutes during an entire day. Moreover, during their time away, their unit's operational effectiveness is reduced by only 5%.

Table 11. Notional Biological HRIP Output – Casualty Threshold SL 2

		Duration Post-Event (Days) – Casualty Threshold SL 2								
	Status	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**15**	**30**
Estimated Population % (or Values per 100)	Total population	100	100	100	100	100	100	100	100	100
	Un	94.0	87.6	80.7	76.2	73.8	71.4	70.6	69.7	69.7
	DOW	0	0	0.5	2.4	5.7	11.0	15.4	29.6	30.3
	KIA	0	0	0	0	0	0	0	0	0
	Fatalities	0	0	0.5	2.4	5.7	11.0	15.4	29.6	30.3
	SNC (SL 1)	Anthrax casualties do not exhibit "mild" (SL 1) symptoms.								
	WIA (SL 2)	6.0	12.4	18.8	21.4	20.5	17.6	14.0	0.7	0
	WIA (SL 3)	Anthrax casualties do not exhibit "severe" (SL 3) symptoms.								
	Total WIAs	6.0	12.4	18.8	21.4	20.5	17.6	14.0	0.7	0
	Total Casualties	**6.0**	**12.4**	**19.3**	**23.8**	**26.2**	**28.6**	**29.4**	**30.3**	**0**

Source: Zirkle et al., *OEA,* 26.

Table 12. Calculation for Notional Example

Status	Duration Post-Event (Days) – Casualty Threshold SL 2								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**15**	**30**
Total population	100	100	100	100	100	100	100	100	100
Un	94.0	87.6	80.7	76.2	73.8	71.4	70.6	69.7	69.7
DOW	0	0	0.5	2.4	5.7	11.0	15.4	29.6	30.3
KIA	0	0	0	0	0	0	0	0	0
Fatalities	0	0	0.5	2.4	5.7	11.0	15.4	29.6	30.3
SNC (SL 1)	Anthrax casualties do not exhibit “mild” (SL 1) symptoms.								
WIA (SL 2)	6.0	12.4	18.8	21.4	20.5	17.6	14.0	0.7	0
WIA (SL 3)	Anthrax casualties do not exhibit “severe” (SL 3) symptoms.								
Number of personnel involved in decon	5	5	5	5	5	5	5	5	5
Duration of decon (days)	.008	.015	.023	.026	.025	.021	.017	0	0
OE-IE	0	0	0	0	0	0	0	0	0
Total OEA	89.0	82.6	75.7	71.2	68.8	66.4	65.6	64.7	64.7

Note: The Total OEA is the minimum OEA value at the point in the day during which decontamination is conducted. The OEA will be higher during the remainder of the day when decontamination is not being conducted.

6. Way Forward

Decontamination is a well-understood and well-documented element of CBRN activity, and the procedures and best practices have been established for decades. The missing elements for the OELM methodology are in the nuances of the process:

- How much time is required for decontamination at each station?
- How many lanes can be opened at one time?
- How many patients can move through simultaneously?
- Can lanes be changed from ambulatory to litter borne as required or are these lanes static once set?

These kinds of questions may require input from SMEs to be answered fully. Therefore, the next step, if greater granularity is required, is to seek input from SMEs (e.g., those at USAMRICD and those who run the Field Management of Chemical and Biological Casualties course in Aberdeen). The equation for the time required at the decontamination station can also be refined or even treated as an optimization to determine ideal lane allocations between ambulatory and litter-borne patients.

C. Indirect Exposure (IX): Combat Stress (CS)

Combat stress, or CS, is "a term used to describe normal physiological, behavioral, and psychosocial reactions experienced before, during or after combat."[94] CS can be caused by a number of different events, including personal injury, engagement with combatants, witnessing injury or death of others, and prolonged exposure to extreme conditions.[95] CS reactions can be negative, causing symptoms previously thought to be mental illnesses, including emotional and cognitive symptoms,[96] or positive, including "increased alertness, exceptional strength, heightened endurance, or tolerance to pain and hardship."[97] CS is defined distinctly from *post-traumatic stress disorder (PTSD)*. CS reactions are expected to occur in the operational environment while post-traumatic stress reactions are defined as occurring after individuals are out of the combat or operational environment.[98]

Values need to determine losses due to CS are difficult to establish because data pertaining to psychological stress effects of military personnel in conventional combat operations—let alone in CBRN situations—are limited.[99] This section is intended to illustrate how CS effects might be estimated as part of the OELM methodology and to begin to describe the process by which the IDA research team proposes to derive values for CS using current definitions, policy, and existing literature.

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94 Department of Defense, "Stress Awareness," accessed May 6, 2014, http://www.defense.gov/specials/stressawareness03/combat.html.

95 Edward A. Brusher, "Combat and Operational Stress Control," in *Combat and Operational Behavior Health*, ed. Elspeth Cameron Ritchie (Falls Church, VA: Office of the Surgeon General, United States Army, 2011), 61, https://ke.army.mil/bordeninstitute/published_volumes/combat_operational/CBM-ch4-final.pdf.

96 Douglas B. Cooper et al., "Association Between Combat Stress and Post-Concussive Symptom Reporting in OEF/OIF [Operational Enduring Freedom/Operation Iraqi Freedom] Service Members with Mild Traumatic Brain Injuries," *Brain Injury* 25, no. 1 (2011): 1, http://informahealthcare.com/doi/abs/10.3109/02699052.2010.531692.

97 Department of Defense, "Stress Awareness."

98 "The American Institute of Stress, "Military Stressors—PTSD, COS," accessed January 15, 2015, http://www.stress.org/military/.

99 An IDA research team is investigating whether enough data exist to estimate CS OELM parameters. If these data exist, the research will explain how these values could be calculated; otherwise, the research is intended to provide recommendations regarding how the data could be gathered to estimate the OELM parameters.

1. Recommended Values

The values provided in Table 13 are notional and for illustrative purposes only to demonstrate how this methodology could be employed provided that actual numbers can be developed.

Table 13. Notional LOELM Factors for CS

Criteria	Values
Number impacted (CSC:total casualties)	1:2
Duration of effect	22 days
ROE	0

Note: These notional LOELM factors are for illustrative purposes only.

For this example, CS starts immediately after the CBRN event, so it is likely that the number of losses due to CS increase as the number of direct casualties increase. Three weeks is a possible duration of CSC symptoms; however, symptoms and the associated degradation could extend beyond the duration of operations.

2. Approach

Research into CS began with a review of academic literature and military manuals and procedures. The research team had two objectives with this approach:

(1) to identify historical ratios of combat stress casualties (CSC) or psychological casualties (PCs)[100] to physiological casualties and fatalities (or non-casualties) in a variety of military and civilian settings; and

(2) to begin to develop injury severity levels that can be correlated to different severities of CS.

To research casualty ratios, the research team used a number of military sources and other government publications that addressed the topics of *psychological* or *behavioral* CS. In addition, university and other research organization publications on the topic of CS were reviewed. Historically, this class of casualties was referred to as combat exhaustion or battle fatigue.[101] Most of the collected sources

[100] The term *combat stress casualty* is used to refer to casualties that result from military-related events, while the term "psychological casualty" is used to refer to casualties that result from events that are civilian in nature. Both terms can apply to CBRN or non-CBRN events.

[101] Charles R. Figley and William P. Nash, *Combat Stress Injury: Theory, Research, and Management* (New York, NY: Routledge, 2007), 35.

discussed casualties in terms of CS or *psychological stress*, but more recently, CS has also been referenced as combat and operational stress (COS).[102]

Initially for this work, the specific focus was on collecting CS ratios for only those CBRN events that occurred in military environments; however, the research team found minimal and incomplete data in this area. As a result, the scope was broadened to include non-CBRN events in both civilian and military settings. It should be noted that in the literature PCs refer to both short-term psychological casualties (similar to those experiencing CS) and long-term psychological casualties (such as those who have developed PTSD). The ultimate focus of this work will be to eventually determine the CSC:WIA ratio for a specified military unit size (company, battalion, brigade, and so forth).

The research team was not able to find a consistent military or civilian standard for CSC:total casualties (WIA + KIA) or PC:total casualties, because the definitions of CSC and PC are inconsistent and there is no uniform measure of the total casualties. Most documented military CBRN events provide little to no quantitative data on CS casualties or PTSD casualties. Moreover, while research into civilian CBRN events has not traditionally measured PC in a consistent manner, more recent studies have captured information potentially relevant to different types of CS such as worried well.[103] Therefore, the research team began by looking at several instances—some civilian and some military—where CS or PC data have been collected and documented to help develop standards going forward. For military cases, the ratios were recorded as CSC:WIA, while for civilian events, the ratios were recorded as PC:WIA (see Table 14).

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[102] Negative reactions occurring from COS are labeled as *combat and operational stress reactions (COSRs)*. See Headquarters, Department of the Army, *Combat and Operational Stress Control Manual for Leaders and Soldiers*, FM 6-22.5 (Washington, DC: Author, 2009), 1-1, http://armypubs.army.mil/doctrine/dr_pubs/dr_a/pdf/fm6_22x5.pdf.

[103] *Worried well* are people who have minimal or no exposure to a CBRN agent but will seek medical care, thus slowing down the medical treatment of genuinely affected patients. See Fred P. Stone, "The 'Well-Worried' Response to CBRN Events: Analysis and Solutions," Counterproliferation Paper No. 40 (Maxwell Air Force Base, AL: Air University, USAF Counterproliferation Center, June 2007), 1, http://www.fas.org/irp/threat/cbw/worried.pdf.

Table 14. Sample CS Data

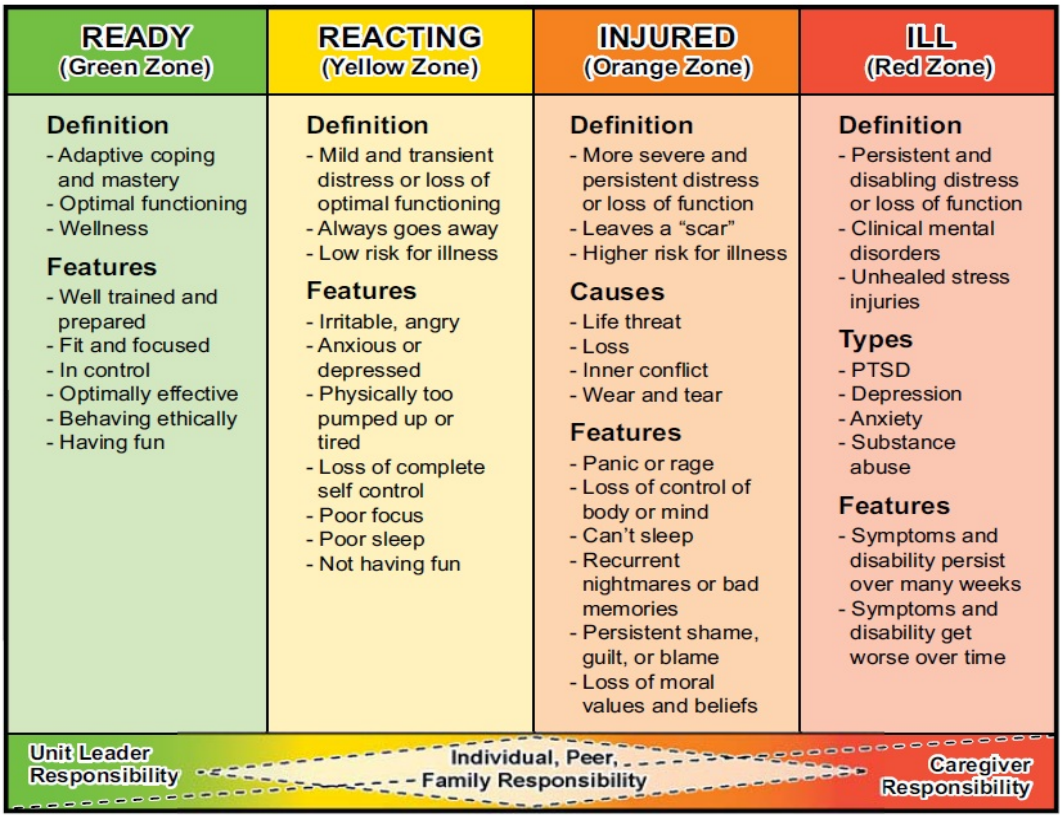
Event	Year(s)	Event Type	CSC:WIA	PC:WIA
European Theater WWII	1942–1945	Non-CBRN	1:3	
European Theater WWII (airborne forces)[a]	1942–1945	Non-CBRN	1:10	
Okinawa WWII (1 month)	1945	Non-CBRN	1:1.8	
Israeli Scud Attack I (includes all casualties) [b]	1991	Non-CBRN		16: 1
Israeli Scud Attack I (excluding unjustified Atropine injections) [b]	1991	Non-CBRN		8:1
Lebanon (height of war)	1982	Non-CBRN	1:1	

Sources: [a] U.S. Marine Corps, *Combat Stress,* FM 90-446/6-22.5/NTTP 1-15M/MCRP 6-11C (Washington, DC: Headquarters, USMC, 2000), 1, http://www.au.af.mil/au/awc/awcgate/usmc/mcrp611c.pdf.

[b] Ross H. Pastel and Elspeth Cameron Ritchie, "Terrorism and Chemical, Biological, Radiological, Nuclear, Explosive Weapons," in *Combat and Operational Behavior Health*, ed. Elspeth Cameron Ritchie (Falls Church, VA: Office of the Surgeon General, United States Army, 2011), 596–598, https://ke.army.mil/bordeninstitute/published_volumes/combat_operational/CBM-ch36-final.pdf.

The root of the challenge in estimating CSC is in the lack of available data and the lack of clarity in the data that are captured. For example, depending on the definition of CS being used at the time that the data were collected, recorded ratios—particularly those pertaining to CBRN events—range widely, from 1 CSC for every 10 PAR to 2,500 CSCs for every 1 PAR.

To develop injury SLs associated with CSCs, the research team started reviewing U.S. military Service doctrine. The Department of the Navy, specifically, the U.S. Marine Corps (USMC) document *Combat and Operational Stress Control* divides the severity of CS symptoms into four zones expressed along a continuum: ready, reacting, injured, and ill, as shown in Figure 7.



Source: U.S. Marine Corps, *Combat and Operational Stress Control,* MCRP 6-11C/NTTP 1-15M (Washington, DC: Department of the Navy, Headquarters United States Marine Corps, 20 December 2010), 1-8. http://www.namb.net/uploadedFiles/COSC%201.pdf.

Figure 7. USMC Combat and Operation Stress Continuum Model

3. Assumptions

Since the values in Table 13 are notional and for illustrative purposes only, there are no assumptions for evaluating CS at this time.

4. Results

For this illustrative example, the IDA research team is estimating CSCs as a function of total casualties. To track day-by-day changes in personnel status, a new CSC value is estimated each day as a function of the new total casualties for that day. In other words, each day that a unit suffers new total casualties that unit also adds new CSCs based on the following:

$$CSC_{day}(t) = \frac{New\ total\ casualties_{day}(t)}{2}$$

These individuals classified as CSCs are considered operationally ineffective: i.e., their ROE is zero. They remain operationally ineffective for 22 days. At the end of day 22 (i.e., on day 23), these individuals go back into the unaffected cohort.

5. Incorporation into the OEA Methodology

Using the OEA notional anthrax example from the earlier IDA publication, *Operational Effectiveness Analysis*,[104] Table 15 provides the HRIP output for the example.

Table 15. Notional Biological HRIP Output – Casualty Threshold SL 2

		Duration Post-Event (Days) – Casualty Threshold SL 2								
	Status	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**15**	**30**
Estimated Population % (or Values per 100)	Total population	100	100	100	100	100	100	100	100	100
	Un	94.0	87.6	80.7	76.2	73.8	71.4	70.6	69.7	69.7
	DOW	0	0	0.5	2.4	5.7	11.0	15.4	29.6	30.3
	KIA	0	0	0	0	0	0	0	0	0
	Fatalities	0	0	0.5	2.4	5.7	11.0	15.4	29.6	30.3
	SNC (SL 1)	Anthrax casualties do not exhibit "mild" (SL 1) symptoms.								
	WIA (SL 2)	6.0	12.4	18.8	21.4	20.5	17.6	14.0	0.7	0
	WIA (SL 3)	Anthrax casualties do not exhibit "severe" (SL 3) symptoms.								
	Total WIAs	6.0	12.4	18.8	21.4	20.5	17.6	14.0	0.7	0
	Total Casualties	**6.0**	**12.4**	**19.3**	**23.8**	**26.2**	**28.6**	**29.4**	**30.3**	**30.3**

Source: Zirkle et al., *OEA*, 26.

The unit's operational effectiveness over time given CS is shown in Table 16. The CSCs on and before day 7 have fully recovered by day 30. With very few new total casualties beyond day 7, and hence few CSCs beyond this day, the unit's operational effectiveness is greater on day 30 than on day 15.

Table 16. Calculation for Notional CS Example

	Duration Post-Event (Days) – Casualty Threshold SL 2								
Status	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**15**	**30**
Total population	100	100	100	100	100	100	100	100	100
Un	94.0	87.6	80.7	76.2	73.8	71.4	70.6	69.7	69.7
DOW	0	0	0.5	2.4	5.7	11.0	15.4	29.6	30.3
KIA	0	0	0	0	0	0	0	0	0
Fatalities	0	0	0.5	2.4	5.7	11.0	15.4	29.6	30.3
SNC (SL 1)	Anthrax casualties do not exhibit "mild" (SL 1) symptoms.								
WIA (SL 2)	6.0	12.4	18.8	21.4	20.5	17.6	14.0	0.7	0
WIA (SL 3)	Anthrax casualties do not exhibit "severe" (SL 3) symptoms.								
Total WIAs	6.0	12.4	18.8	21.4	20.5	17.6	14.0	0.7	0
Total Casualties	6.0	12.4	19.3	244444 443.8	26.2	28.6	29.4	30.3	30.3
Number of CSCs	3.0	6.2	9.7	11.9	13.1	14.3	14.7	15.2	0.5
Total OEA	**91.0**	**81.4**	**71.0**	**64.3**	**60.7**	**57.1**	**55.9**	**54.5**	**69.2**

[104] Zirkle et al., *OEA.*

6. Way Forward

Additional extensive and in-depth analyses of historical data are required to develop a more accurate assessment of the CS to total casualties ratio. For example, the USMC color-coded its stress features,[105] and U.S. Army stress reactions of *mild* and *severe* COSRs could potentially be linked to existing HRIP SLs for the evaluation of CSCs.[106]

Earlier, Table 14 provides an initial sampling of the type of data available, but a much deeper analysis into source documents and specific event factors will help complete the table and further shape the overall OELM ratio. Examples of areas requiring more research include the PAR for CS, the PAR for the entire event, and the total numbers of PCs and CSCs for each event. Further, the types and varying levels of CS should be considered as relevant information becomes available.

[105] U.S. Marine Corps, *Combat and Operational Stress Control*, 1-7–1-14.

[106] D. S. Disraelly et al., "A New Methodology for Estimating Nerve Agent (Sarin (GB)/VX) Casualties as a Function of Time: Defining the Human Injury Response Profile Nerve Agent Methodology," *Journal of Chemical Health and Safety* 18, no. 5 (2011): 7, http://www.sciencedirect.com/science/article/pii/S1871553210000927.

6. Summary and Conclusions

Currently, there are few ways to estimate the collateral effects of individual military personnel and units that lose operational effectiveness due to AAPRs and IXs. The general OELM methodology provides a framework for evaluating the numbers of additional CBRN losses to the unit due to the indirect effects of the event in terms of fraction of impacted population, operational effectiveness decrement, and duration of effects, as illustrated in Table 17. In addition, for each category, several examples are provided that can be explored for future inclusion later. The full range of activities and factors that could be included has not yet been evaluated.

Table 17. General OELM Parameters

	MCMs	NMCMs	RAs	IXs
Examples	MMCM-vaccine MMCM-PEP	NMCM-IPE (MOPP) NMCM-CPE NMCM-PHI (social distancing) NMCM-PHI (quarantine)	RA-Decon (ambulatory) RA-Decon (patient) RA-Decon (equipment) RA-Buddy Aid RA-Reconnaissance	IX-CS IX-Glass breakage IX-Flash blindness
Number impacted	Fraction of impacted vs. PAR, PE-PAR or WIA (depending on the MCM)	Fraction of impacted vs. PAR, PE-PAR or WIA (depending on the NMCM)	Ratio of Un:WIA	Ratio of Un:WIA
Duration of impact	Hours to weeks (duration of the impact)	Hours to days	Hours to days	Days to mission end
ROE	Partially effective to operationally ineffective	Partially effective to operationally ineffective	Operationally ineffective	Spectrum from partially effective to casualty (operationally ineffective)
Return to duty (RTD)	Protracted, possibly time-limited RTD	Full RTD	Full RTD	Possible; dependent on severity of stress

The OELM methodology described in this paper is recommended as the first methodology that calculates operational effectiveness losses across a spectrum of categories. It further aims to demonstrate the first general framework for estimating increases in the numbers of individuals who are lost to a unit as a result of the materiel, activities, and IXs associated with a CBRN event (e.g., adverse prophylaxis reactions, establishing a decontamination station, and CS). Although previous models have estimated unit performance

following CB attacks, most of these models have not taken into account the additional anticipated losses to an individual or a unit that result from MCM use, NMCMs, RAs, or IXs, and no known model has taken into account all four.

The OELM methodology builds on the proposed OEA methodology, providing a process that is simple, clear, and relatively easy to assess and to execute if data are available. The introduction of the OELM methodology may facilitate improvement in the estimation of the operational effects on individual or military units following a CBRN event. In addition, while developed for use with the OEA methodology, OELMs could be used with other models and methodologies.

Using the HRIP casualty estimation methodology for a given CBRN attack in combination with the OEA methodology and the OELM process, the military operational planner has a new quantitative, qualitative, and graphical representation of the unit's operational effectiveness as a function of effective personnel, casualties, fatalities, SNCs, and OELMs. This output can also be combined with current DOD risk assessment procedures to determine the level of risk to the unit associated with a given mission following a CBRN attack. Examples of the parameters for several illustrative examples are shown throughout the paper.

The next steps in developing the OELM process involve identifying and prioritizing the relevant OELMs and then assessing the available data to evaluate the recommended values for each category and applicable response activities of OELMs. Following the general framework proposed in this paper, IDA proposes to do additional proof-of-concept OELM development, focusing on completing the CSC-recommended values and identifying and evaluating additional medical materiel and non-medical countermeasures. These areas will be evaluated through literature review and additional research that enables the collection of real-world data and SME elicitation. Specifically, the research team will focus on the development of OELM parameters for biological agents (and the associated MMCMs) and for chemical and radiological hazards and sample-associated NMCMs and RAs. In addition, the research team will pursue additional research on IX (to begin with CS) to evaluate the potential for the development of appropriate and documentable OELM parameters.

Appendix A
Illustrations

Figures

Tables

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Appendix B
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Appendix C
Glossary

Buddy aid — "Acute medical care (first aid) provided by a non-medical Service member to another person."[1]

Casualties — "Any person who is lost to his organization by reason of having been declared dead, wounded, diseased, detained, captured, or missing …"[2] "as a result of exposure to a chemical agent, biological agent, radiological agent, or nuclear flash, blast, heat or radiation."[3] Casualties include both non-fatal casualties and fatalities.

Casualty multipliers — Factors and requirements that render some individuals or some fraction of the unit ineffective or partially effective because of the collateral impacts on the personnel or requirements placed on the personnel by the chemical, biological, radiological, and nuclear (CBRN) event or in preparation for or response to such an event.

Category — General terminology to describe the additional, collateral factors that influence operational effectiveness (i.e., medical countermeasures (MCMs), non-medical countermeasures (NMCMs), response activities (RAs), and indirect exposures (IXs)).

CBRN Event — Any event that causes a CBRN-induced illness or injury, whether intentional, naturally occurring, or accidental.

Class — Within each subcategory, describes specific activities and actions in preparation or response to a CBRN event (Activities and Actions in Preparation or Response to the Event (AAPR)) and potentially] contingent on the type of CBRN event.

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1 Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, Joint Publication 1-02 (Washington, DC: November 2010), 26, http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf.

2 North Atlantic Treaty Organization (NATO) Standardization Agency (NSA), *NATO Glossary of Terms and Definitions (English and French)*, Allied Administration Publication (AAP)-06, Edition 2012 Version 2 (hereafter referred to as AAP-06 (2012)) (Belgium: NSA, 2012), 2-C-2.

3 Deena S. Disraelly et al., "A New Methodology for Chemical, Biological, Radiological, and Nuclear [CBRN] Casualty Estimation over Time," *Journal of Defense Modeling and Simulation* 7, no. 4 (2010): 228, http://dms.sagepub.com/content/7/4/226.full.pdf+html.

Cohort	A term to describe personnel status at a given point in time. Individuals may move from one cohort to another at different points in time depending on their exposure and the collateral effects of their activities and actions in preparation or response to a CBRN event (AAPR).
Collateral effects (or impacts)	Consequences or impacts experienced in advance of, in concert with, subordinate to, or subsequent to the direct casualties that result from a CBRN event that reduce operational effectiveness of individuals or units.
Collective protection equipment	Equipment used to provide protection "to a group of individuals that permits relaxation of individual chemical, biological, radiological, and nuclear protection."[4]
Combat stress (CS)	"The mental, emotional or physical tension, strain, or distress resulting from exposure to combat and combat-related conditions … Combat stress reactions are the result of exposure to the same conditions during military actions that cause physical injury and disease in battle or its immediate aftermath … Rates of combat stress casualties vary greatly, with higher ratios during lengthy periods of intense combat … [combat stress reactions] may also arise from combat-like conditions present during military operations other than war."[5]
Decontamination	Use of unaffected, mission-capable forces to perform the processes necessary to mitigate exposure and take the required actions to allow contaminated individuals and equipment to be returned to duty and contaminated patients to be stabilized for medical treatment.
Died of wounds	An individual who dies after seeking medical attention.
Fatality	An individual in the unit who dies outright or who dies either before or after seeking medical attention. The Human Response Injury Profile (HRIP) methodology distinguishes between two types fatalities: those who die outright or before seeking medical attention, known as killed in action (KIA),[6] and those who die after seeking medical attention, known as died of wounds (DOW).[7]
Fully effective	"Little or no adverse impact on mission capability. First aid or minor medical treatment."[8]

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4 Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, 36.

5 U.S. Marine Corps, *Combat Stress*, FM 90-446/6-22.5/NTTP 1-15M/MMCRP 6-11C (Washington, DC: Headquarters, USMC, 2000), Preface, http://www.au.af.mil/au/awc/awcgate/usmc/mcrp611c.pdf.

6 AAP-06 (2012), 2-K-1.

7 Ibid., 2-D-6.

8 Robert A. Zirkle et al., *Operational Effectiveness Analysis (OEA)*, Document D-4666 (Alexandria, VA: Institute for Defense Analyses (IDA), August 2012), 21. Note that Zirkle et al. uses the term "effective" rather than "fully effective."

Ineffective	"Loss of ability to accomplish the mission or mission failure. Death or permanent disability."[9]
Indirect exposures (IXs)	Exposures that produce symptoms in individuals who were not directly exposed to the CBRN event, agent, or hazard in sufficient quantities to produce physiological symptoms but were aware of the event because of being present, witnessing the event at a distance, or experiencing the event through secondary or tertiary effects or communication and contact with others.
Individual protective equipment (IPE)	"In chemical, biological, radiological, or nuclear operations, the personal clothing and equipment required to protect an individual from chemical, biological, and radiological hazards and some nuclear hazards."[10]
Insult	Chemical and biological agents, radiation, blast, or thermal energy that result from CBRN events that produce direct physiological symptoms and casualties.
Killed in action (KIA)	An individual who dies outright or before seeking medical attention.
Losses due to operational effectiveness loss multipliers (LOELMs)	The loss of individuals (or fraction of a unit) as calculated by the operational effectiveness loss multipliers (OELMs). While some individuals (or fraction of the military unit) may be ineffective (and thereby a loss or casualty) directly due to their responsibilities, others may become symptomatic non-casualties (SNCs) or casualties due to side, or adverse, effects associated with the OELMs. These LOELMs are distinct from the HRIP-defined casualties, as noted previously because they are not always a complete loss to the unit, but, when they are, the losses are due to the collateral effects: ancillary procedures, requirements, and exposures that stem from the unique nature of a CBRN event rather than loss due not to the physiological symptoms resulting directly from the CBRN *insult;*[11] The loss of operational effectiveness of these individuals (or fraction of a military unit) as calculated by the OELM methodology is not fixed and can change as a function of time.
Medical counter-measures (MCMs)	Prevention and protection measures and procedures to eliminate or mitigate exposures to chemical, biological, and radiological hazards, as well as nuclear-weapon-related radiation, blast, and thermal insults. According to the Department of Defense (DOD), medical countermeasures "range from the routine management of medical materiel used for individual protection to planning responses for events that may produce catastrophic numbers of casualties."[12] They include those things

[9] Ibid.

[10] Department of Defense, *Department of Defense Dictionary of Military and Associated Terms*, 117–118.

[11] Insults are defined as chemical and biological agents, radiation, blast, or thermal energy resulting from CBRN events that produce direct physiological symptoms and casualties.

[12] Department of Defense. *Health Service Support.* JP 4-02. Washington, DC: Joint Staff, 26 July 2012, D-21, http://www.dtic.mil/doctrine/new_pubs/jp4_02.pdf.

	that "directly affect the biology, metabolism, or status of the organism"[13] or the individual experiencing the CBRN physiological symptoms.
Medical materiel countermeasures (MMCMs)	Pharmaceutical countermeasures including three classes: vaccines, prophylaxis (both pre- and post-exposure), and post-exposure treatment (such as antibiotics).
Non-fatal casualties	See Wounded in Action (WIA).
Non-medical countermeasures (NMCMs)	NMCMs are "everything else [not affecting the biology or metabolism of an individual experiencing physiological symptoms due to a CBRN event]: behavioral, materiel, social."[14] NMCMs against CBRN include those materiel, actions, and procedures—non-medical in nature—necessary to mitigate or prevent further exposure to the CBRN agent.
Operational effectiveness	The ability of personnel or units to complete an assigned mission.
Operational effectiveness loss multipliers (OELMs)	Factors and requirements, including AAPRs, that render some individuals or some fraction of the unit ineffective or partially effective because of the collateral impacts on personnel occasioned by the CBRN event or requirements placed on personnel in preparation for or response to such an event.
Operational effectiveness methodology	"An alternate methodology that utilizes the HRIP casualty estimation methodology, to represent the unit's operational ability to complete a mission following a CBRN event."[15]
Partially effective	"Significantly degraded mission capability, unit readiness, or personal disability."[16]
Post-event population at risk (PE-PAR)	The total number of troops to whom OELMs can be applied. Depending on the nature of the loss multiplier and the decision of the commander, this group can either include only those unaffected by the CBRN incident at any or all points in time or it could be defined by as anyone who is not considered a casualty or fatality based on their HRIP WIA status.

[13] Michael Hopmeier, "Issues Associated with Population Protection from Disaster and Infectious Disease and the Role of Public Health" (briefing, Triangle Lecture Series, Center for Public Health Preparedness and Research, The Rollins School of Public Health of Emory University and The Department of Emergency Medicine, Emory University School of Medicine, Atlanta, GA, March 22, 2006).

[14] Ibid.

[15] Zirkle et al., *OEA,* iv.

[16] Ibid., 21.

Population at risk (PAR)	The total number of troops included in the scenario characterization.[17]
Public health interventions	Those actions—non-medical in nature—necessary to mitigate or prevent further exposure to the CBRN agent Two examples of these actions include social distancing and quarantining of personnel.
Residual operational effectiveness (ROE)	The fraction of operational effectiveness that remains after the administration of any OELM results in some loss of operational effectiveness. For those who are fully effective, the ROE is 1. For those who are ineffective, the loss of operational effectiveness is 1 and the ROE is 0. For those who are partially effective, the ROE is the loss of operational effectiveness subtracted from 1.
Response activities (RAs)	Tasks or actions taken to "[address] the immediate and short-term effects of the disaster or emergency."[18]
Scenario	An account or synopsis of a projected course of action or events, with a focus on the strategic level of warfare. Scenarios include information such as threat, contexts and backgrounds, assumptions, constraints, limitations, strategic objectives, and other planning considerations. A scenario is intended to represent a plausible challenge(s) and may not reflect the most likely events.
Subcategory	Further divides and differentiates each OELM category.
Subclass	Additional information on the AAPRs within each class that may be applicable to different portions of the PAR or for varying times. For example, some small portion of the military population that is allergic to doxycycline might be administered ciprofloxacin post-exposure prophylaxis (PEP). Similarly, during decontamination, different jobs assignments will last longer than others, thereby varying the duration of operational effectiveness loss for the different unit members performing each task.

[17] D. S. Disraelly et al., "A New Methodology for Estimating Nerve Agent (Sarin (GB)/VX) Casualties as a Function of Time: Implementing the Human Response Injury Profile Nerve Agent Methodology," *Journal of Chemical Health and Safety* 18, no. 5 (2011): 15, http://www.sciencedirect.com/science/article/pii/S1871553210000939#.

[18] Department of Veterans Affairs. *Veterans Health Administration Emergency Management Program Procedures.* VHA Handbook 0320.2 (Washington DC: Veterans Health Administration, June 2000), A-3, http://www.va.gov/vhapublications/ViewPublication.asp?pub_ID=326. In VHA Handbook 0320.2, RAs are defined under the term "RESPONSE."

Symptomatic non-casualties

"Those individuals, or the fraction of the unit, who exhibit symptoms but whose symptoms are not yet of a severity requiring them to (or resulting in the expectation that they would) seek medical attention."[19] May include those who experience symptoms due to direct exposure, whether the source was hostile, unintentional, or accidental, and those who experience symptoms as a result of the collateral effects of the CBRN event.

Unaffected (Un)

The individuals in the unit, or fraction of the unit, who are directly unaffected by the CBRN event. They "may be unaffected for several reasons including, but not limited to: 1) unexposed; 2) exposed at levels that will not result in symptoms or have not yet caused symptoms; or 3) protected by non-medical countermeasures including IPE and collective protection and/or MCM,"[20] with no adverse effects arising from the use of these countermeasures.

Wounded in Action (WIA) (also referred to as non-fatal casualties)

A casualty "other than 'killed in action' who has incurred an injury due to an external agent or cause;"[21] WIA is typically applied to battle casualties, those that are "the direct result of hostile action, sustained in combat or relating thereto or sustained going to or returning from a combat mission."[22]
To avoid introduction of additional terminology and for the OEA and OELM methodologies, WIA is extended to include non-fatal casualties incurred in the line of duty, "injury[ies], illness, or disease … incurred or aggravated as a result of military duty not due to gross negligence or misconduct"[23] and includes those who experience injury due to direct exposure, whether the source was hostile, unintentional, or accidental, and those who experience injury as a result of the collateral effects of the CBRN event[24]

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19 Zirkle et al., *OEA,* 14.

20 Ibid., 13.

21 North Atlantic Treaty Organization (NATO) Standardization Agency (NSA), *NATO Glossary of Terms and Definitions (English and French)*, Allied Administration Publication (AAP)-6 Edition 2008) (hereafter referred to as AAP-6 (2008)) (Belgium: NSA, 2008), 2-W-2, https://www.fas.org/irp/doddir/other/nato2008.pdf.

AAP-06 proposes a slightly different definition: a casualty "who has incurred a non-fatal injury due to an external agent or cause as a result of hostile action." (AAP-06 (2012), 2-W-2.) To avoid any confusion or implication that WIAs cannot eventually die as a result of their injuries, the earlier definition from AAP-6 (2008) is used for the OEA methodology.

22 AAP-06 (2012), 2-B-2.

23 Department of Defense, *Reserve Component Medical Care and Incapacitation Pay for Line of Duty Conditions*, DoD Directive (DoDD) 1241.01 (Washington, DC: USD(P&R), April 23, 2007), 2, http://www.dtic.mil/whs/directives/corres/pdf/124101p.pdf.

24 Some individuals who experience collateral effects and participate in AAPRs will have reduced operational effectiveness but will not be casualties.

Appendix D
Abbreviations

AAPR	activities and actions in preparation or response
AFMAN	Air Force Manual
AFTTP	Air Force Tactics, Techniques, and Procedures
BCT	Brigade Combat Team
Cas	casualties
CB	chemical or biological
CBDP	Chemical/Biological Defense Program
CBRN	Chemical, Biological, Radiological and Nuclear
CJCS	Chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CMC	casualties due to medical countermeasures
COS	combat and operational stress
COSR	Combat and Operational Stress Reaction
CPE	collective protection equipment
CRN	chemical, radiological, and nuclear
CS	combat stress
CSC	combat stress casualties
DHCC	DoD Deployment Health Clinical Center
DNBI	disease non-battle injury
DOD	Department of Defense
DOW	died of wounds
DTRA	Defense Threat Reduction Agency
FE	fully effective
FM	Field Manual
Ftl	fatalities
HRIP	Human Response Injury Profile
IDA	Institute for Defense Analyses
IE	ineffective
IPE	individual protective equipment

ISAF	International Security and Assistance Force
IX	indirect exposure
JEM	Joint Effects Model
JP	Joint Publication
JWARN	Joint Warning Network
KIA	killed in action
LOE	operational effectiveness loss
LOELM	loss due to operational effectiveness loss multiplier
MCM	medical countermeasure
MCRP	Marine Corps Reference Publication
MCWP	Marine Corps Warfighting Publication
MMCM	medical materiel countermeasure
MMWR	Mortality and Morbidity Weekly Report
MOPP	mission-oriented protective posture
MTTP	multi-Service tactics, techniques, and procedures
NATO	North Atlantic Treaty Organization
NAVMED	U.S. Navy Medicine Publication
NBC CREST	Nuclear, Biological, and Chemical Casualty and Resource Estimation Support Tool
NMCM	non-medical countermeasure
NTTP	Naval Tactics, Techniques, and Procedures
OEA	operational effectiveness analysis
OEF	Operational Enduring Freedom
OEI	Operation Enduring Freedom
OE-FE	individual s who are fully operationally effective
OE-IE	individuals who received the MMCM and then became ineffective
OELM	operational effectiveness loss multiplier
OE-PE	individuals who received the MMCM and then became partially effective
OIF	Operation Iraqi Freedom
PAR	population at risk
PC	psychological casualty
PE	partially effective
PEP	post-exposure prophylaxis
PE-PAR	post-event population at risk
PHI	public health intervention

PTSD	post-traumatic stress disorder
RA	response activity
ROE	Residual Operational Effectiveness
RTD	Return to Duty
SL	severity level
SME	subject matter expert
SNC	symptomatic non-casualties
SOP	standard operating procedure
TTP	tactics, techniques, and procedures
Un	unaffected
USA	United States Army
USAMRICD	United States Army Medical Research Institute of Chemical Defense
USAMRIID	United States Medical Research Institute of Infectious Disease
USMC	United States Marine Corps
USN	United States Navy
VA	Department of Veterans Affairs
WIA	wounded in action

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